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ABSTRACT

This document reports on a workshop held in Arlington, Virginia, in 1998. The purpose of the forum was to share knowledge for strengthening graduate education in science and engineering, and learning from one another with the participation of faculty, administrators, staff, students, funding agents, leaders in business and industry, and representatives of professional societies and governmental agencies. Sections include: (1) Introductory Remarks: WV-Madison, NSF, and NSB; (2) Moderated Discussion among Representative Stakeholders; (3) Panel on Strategies for Change in Serving Educational Infrastructure; (4) Panel on Strategies for Change in Serving Students and Society; (5) Panel on Strategies for Change in Serving Business and Industry; (6) The Current Status of Graduate Education; (7) The Current System: Issues to Consider; (8) Change Drivers: Internal and External Forces for Change; (9) Conditions for Change: Context, Structure, and Culture; and (10) Promising Practices and Strategies for Implementation. Appendices include both an organizational and alphabetical participant list. (YDS)

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National Institute for Science Education

University of Wisconsin-Madison · National Center for Improving Science Education

Workshop Report No. 7

Synthesis of the Science, Mathematics, Engineering and Technology Graduate Education Forum

Arlington, Virginia, 29-30 June 1998

Terrence S. Millar, Sarah A. Mason, Ramona L. Gunter, & Susan B. Millar

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The NISE issues papers to facilitate the exchange of ideas among the research and development community in science, mathematics, engineering, and technology (SMET) education and leading reformers of SMET education as found in schools, universities, and professional organizations across the country. The NISE Occasional Papers provide comment and analysis on current issues in SMET education including1 SMET innovations and practices. The papers in the NISE Research Monograph series report findings of original research. The NISE Conference and Workshop Reports result from conferences, forums, and workshops sponsored by the NISE. In addition to these three publication series, the NISE publishes Briefs on a variety of SMET issues.

The research and preparation for the Forum and this Synthesis were supported by a cooperative agreement between the National Science Foundation and the University of Wisconsin-Madison (Cooperative Agreement No. RED-9452971) and by the Graduate School of the UW-Madison. Additional NSF support for the Forum and Synthesis was provided by the Division of Science Resources Studies in the Directorate for Social, Behavioral, and Economic Sciences. At UW-Madison, the National Institute for Science Education is housed in the Wisconsin Center for Education Research and is a collaborative effort of the College of Agricultural and Life Sciences, the School of Education, the College of Engineering, the Graduate School, and the College of Letters and Science. The collaborative effort also is joined by the National Center for improving Science Education, Washington, DC. Any opinions, findings, or conclusions are those of the authors and do not necessarily reflect the view of the supporting agencies.

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Arlington, Virginia, 29-30 June 1998

Terrence S. Millar, Sarah A. Mason, Ramona L. Gunter, & Susan B. Millar

National Institute for Science Education
University of Wisconsin-Madison

December 1999

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Preface

This Synthesis is intended as a contribution to our understanding of science, mathematics, engineering, and technology (SMET) graduate education. Over the last 100 years, the United States has created the premier graduate education enterprise in the world. Graduate education is part of an information- and research-driven cultural transformation that rivals the industrial revolution. This distributed pluralistic collage of learning, research and professional development interacts with numerous other driving forces of our time in ways that are diverse in dimension and scale. The resulting complexity makes understanding graduate education difficult-it has a robust, creative, fractal nature.

Over the past three decades, numerous meetings, studies, and reports have focused on issues of graduate education. The National Institute for Science Education Forum and the Synthesis follow this tradition, affirming the reflective nature of the graduate education enterprise. The Forum had traditional "linear" elements such as sequential panel speakers addressing issues at higher levels of abstraction. However the organizers also fostered "parallel distributed" interactions among participants, drawing on their particular experiences. These interactions took place in simultaneous presentations by subsets of the 45 Forum Featured Practices and in written feedback by all participants during small group breakout sessions. In addition, the organizers provided participants, in advance of the forum, with ***Descriptions of Programs and Strategies for Change*** (*DPSC*), a document designed both to introduce the featured practices and to provide a resource for use after the forum.[1]

We hope that this Synthesis and the *DPSC* will assist the reader in better understanding the forces at play in the domain of graduate education and the innovative ways programs from around the country have responded to those forces. We resist the impulse for an "Executive Summary" because the fractal nature of the patterns argues against such an exercise. We aim instead, to borrow a phrase from Clifford Geertz, for a thick **description.**[2]

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1. National Institute for Science Education, ***Descriptions of programs and strategies for change: Strengthening graduate education in science and engineering*** (Madison: University of Wisconsin-Madison, 1998).
2. ***Geertz, C., The interpretation of cultures: Selected essays (New*** York: Basic Books, 1973), 3-32.

Graduate Education Forum

Strengthening Graduate Education in Science and Engineering: Promising Practices and Strategies for Implementation

Sponsored by the National Science Foundation and the University of Wisconsin-Madison

June 29-30, 1998, Key Bridge Marriott Hotel Arlington, VA

Final Agenda

Sunday, June 28, 1998

4:00pm - 7:00pm Registration and Exhibit set-up. Lower Level Lobby near the Capital Tower elevators

Monday, June 29, 1998

Directions for graduate education in science and engineering: Why should there be change and innovation for the 21st century?

Morning		Afternoon	
7:00 - 8:15	Registration and Exhibit check-in *Potomac Ballroom Foyer*	12:00 - 1:00	Buffet Lunch *View Dining Room (top floor)*
7:15 - 8:15	Continental Breakfast *Lower Level Lobby*	1:00 - 2:10	Featured Practice Exhibits *
8:30 - 8:40	Introduction and Welcome *Potomac Ballroom*	2:10 - 3:10	Featured Practice Cluster Presentations *
8:40 - 8:55	NSF Overview	3:10 - 3:30	Refreshment Break *Lower Level Lobby*
8:55 - 9:10	National Science Board Overview	3:30 - 4:30	Featured Practice Cluster Presentations *
9:10 - 10:20	Moderated Discussion among leaders in business, industry, government, and professional organizations	4:30 - 4:40	Break *Lobby*
10:20 - 10:30	Forum Overview	4:40 - 5:40	Featured Practice Cluster Presentations *
10:30 - 10:50	Refreshment Break	6:00 - 7:00	Reception - Sponsored by the University of Wisconsin-Madison Graduate School *View Ballroom*
10:50 - 12:00	Small Group Breakout Session #1 *Assigned rooms*		

**Please see Featured Practice exhibit and cluster presentation maps for locations.*

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Tuesday, June 30, 1998

Strategies for Implementing and Maintaining Promising Practices

Morning

7:15 - 8:00	Continental Breakfast *Lower Level Lobby*
8:15 - 9:20	Panel on Strategies for Change in Serving Educational Infrastructure *Potomac Ballroom*
9:20 - 9:35	Refreshment Break *Potomac Ballroom Foyer*
9:35 - 10:40	Panel on Strategies for Change in Serving Students and Society *Potomac Ballroom*
10: 40 - 10:50	Break
10:50 - 12:00	Small Group Breakout Session #2 *Assigned rooms*

Afternoon

12:00 - 1:00	Buffet Lunch *View Dining Room (top floor)*
1:00 - 2:10	Panel on Strategies for Change in Serving Business and Industry *Potomac Ballroom*
2:10 - 2:20	Break
2:20 - 3:20	Small Group Breakout Session #3 *Assigned rooms*
3:30 - 4:15	Synthesis and Vision *Potomac Ballroom*
4:15 - 4:30	Complete Evaluation Forms

Please remember to fill out your evaluation form

Introduction

In July 1997, the National Science Foundation asked the National Institute for Science Education (NISE) and the Graduate School of the University of Wisconsin-Madison to research, plan, and execute a National Forum on graduate education. A cross-directorate working group at NSF had spent eight months prior to that time developing several themes that they hoped would be addressed at such a forum. In particular, they suggested a focus on how academic communities and organizations around the nation had been responding to the forces on, and the calls for change in, graduate education over the past 25 years.

The NISE and the Graduate School formed an extensive committee of university faculty, administrators, and staff to further research and develop the ideas of the NSF group. Eventually the campus committee broadened its membership to include representatives from a number of national organizations actively concerned with graduate education. The resulting forum was intended to help strengthen the nation's graduate education in science and engineering through informed dialogues among major stakeholders. The goal was to foster ***structured conversations*** among these stakeholders: faculty, administrators, staff, scholars, students, funding agents, leaders in business and industry, and representatives of professional societies and governmental agencies.

The forum was shaped by two primary purposes:

1. To share what has been learned about some of the ***featured practices*** for strengthening graduate education in science and engineering, and

2. To learn from one another about alternative strategies for ***successfully implementing*** change and innovation.

The structured conversations that animated the agenda were introduced by presentations intended to provide a foundation and framework for fruitful discussion. These presentations focused on past, present, and future visions of graduate education in science and engineering. Speakers charted key successes and failures of previous efforts to initiate and implement innovation, examined recent national reports calling for change-including a range of alternative approaches-and advanced the proposition that change and innovation require serious consideration if our universities are to embrace the challenges that our society faces at the dawn of a new century.

Consonant with the primary purposes, the remainder of the forum was organized around two sets of conversations. The first set focused on featured practices for strengthening graduate education in science and engineering at the individual, department, program, college, institutional, and interinstitutional levels. The second set focused on strategies for initiating and implementing change and innovation. Participants were invited to compare and contrast models of change and to describe alternate strategies for serving *educational infrastructure, business and industry,* and

students and society. The reflections of participants were captured by individual and group think pieces that were written in small group breakout sessions.

This document is an attempt to capture the rich texture and content of the Forum's structured conversations through a careful analysis and synthesis of the written think pieces that the participants produced. It is organized partially to reflect the Forum structure, but also to move beyond what is possible at such an event in real time by including an analysis of the written feedback from participants and an integration of that analysis with the other material from the Forum. This "other material" includes excerpts from the ***Descriptions of Programs and Strategies for Change (DPSC)***.

The "Summary Introductory Remarks and Panel Presentations" section of the ***Synthesis*** provides brief **précis** of the introductory remarks and the four panel discussions. Quotes from the panelists in this and the following sections are set off in ***italics***. The final and main section of the ***Synthesis*** is organized into subsections around issues that emerged in an analysis of the think pieces. Each of the thematic subsections presents quotes from various panelists, in ***italics***, and think piece contributors, indented in smaller type. In addition, most subsections cite Featured Practices from the ***DPSC***. These multiple ***DPSC*** references allow the reader to reflect on the comments of Forum participants in light of the cited programs. In the interest of brevity, citations follow the following convention:

DPSC **citations**

Featured Practice – Institution ***(DPSC***, pp. *O-O)* ***[Synthesis*** pp. O-O]

where "***(DPSC*** pp. –)" gives the ***DPSC*** pages for the cited material, and "***[Synthesis*** pp. –]" gives pages in this document where other relevant quotes about this program are previously cited.

Summary Introductory Remarks and Panel Presentations

Introductory Remarks: UW-Madison, NSF, and NSB

Virginia Hinshaw, ***Dean of the Graduate School and Senior Research Officer, University of Wisconsin-Madison***
Joseph Bordogna, ***Acting Deputy Director of the National Science Foundation***
Eamon Kelly, ***Chair of the National Science Board***

Dean Virginia Hinshaw welcomed the Forum participants and observed that there is much to celebrate in graduate education in the United States today, including very positive changes over the past three decades in access and diversity. She noted that the, Forum was about change, in particular, strategies for change of successful programs in these changing times. Dean Hinshaw reminded the participants that the Forum would focus on strategies for changing programs for at least one of three broad purposes: serving educational infrastructure, serving students and society, and serving business and industry.

Acting NSF Deputy Director Joseph Bordogna noted that a basic tenet of NSF's mission is to ensure the vitality of the human resource base of science, mathematics, and engineering in the United States and to reinforce its diversity. He observed that everyone present was aware of criticisms of the United States' system of doctoral education and remarked that the Forum had a pedigree of past workshops and reports upon whose proverbial shoulders it stood.

He mentioned that the National Academy of Sciences 1995 report ***Reshaping the Graduate Education of Scientists and Engineers,***[1] better known as the COSEPUP Report, took a balanced look at the topic, noting challenges that our graduate schools face in times of rapid change. Bordogna noted that the litany of concerns it raised is quite familiar: our system is too rigid, too standardized, too compartmentalized, too narrow, and too reticent about realistic career options for students. Bordogna then said that it is not this litany, but rather our vision of the future that should guide our actions; the COSEPUP Report recommended that future doctoral process should produce more versatile graduates able to embrace a wider spectrum of career opportunities. He said that he was quite excited about the Forum's focus-viable, practical, innovative practices that really work to achieve these and other critical goals.

Bordogna then focused on two aspects of the change that now confronts the nation, ***its rapidity and its complexity. One study by Don Kash and Bob Rycroft,[2] two visionaries in science and technology policy, found that the most successful commercial technologies have indeed become more complex in recent decades. In the 1970s, a quarter century ago, nearly 60% of the world's top exports were simple products. Today it's just the reverse: 60% are complex products, requiring complex processes to produce. To make a long analysis short, the future***

1. National Academy of Sciences, ***Reshaping the graduate education of scientists and engineers*** (Washington, DC: National Academy Press, 1995).
2. D. E. Kash, & R. W. Rycroft, ***U.S. energy policy: Crisis and complacency*** (Norman: University of Oklahoma Press, 1984).

belongs to those who can make sense of the complex. It is our task to prepare science and engineering students to shape a world now driven by that type of change. We need to look forward to enabling and molding what is to come, even though we do not quite understand that future. As Tennessee Williams put it, there is a time for departure, even when there is no certain place to go. This is one of those times, and this workshop can help NSF to guide the frontier of excellence in human capability into the future with your help.

Our first theme, that of highlighting practices that serve students and society, is brought to life in a program created at Rice University for underrepresented groups in the computational sciences. The program challenges archaic admissions policies, noting that some students with marginal GRE scores have become research stars. It views standardized tests as preventing "the nation from tapping into a large part of its human resources, creativity and intellect. We have learned to put great value in what we measure, and have forgotten to ask if this measure is flawed concerning what we value. These tests are far from God-given. Here we need to play philosopher more, and mathematician less." So playing philosopher, let us ask how we can help universities reward diversity. Not the somewhat vacuous amorphous rainbow, but a truly valuable resource-a diversity of intellect. What inspires faculty to serve most effectively as mentors for all students? Which university efforts are especially: successful at attracting and nurturing members of underrepresented groups? How can NSF challenge our grant review panelists to think broadly and inclusively about indicators of promising talent? You can help us cultivate this critical resource, help us to face the future with all parts of our society engaged, with full participation in science and technology by all citizens.

As Chair of the National Science Board, Dr. Eamon Kelly noted that ***the current model for federal support of graduate education in academic institutions is derived from the proposal prepared for the president at the end of the Second World War by Vannevar Bush, director of the Office of Scientific Research and Development.*** [3] *. . . The validity of Bush's argument has been borne out by our national experience over the last half-century. Nonetheless, a re-evaluation and refinement of the federal role in graduate education is essential: today. Since the initiation of the government-university partnership, U.S. society has become larger, more diverse, and more urban and the economy-and science itself-are becoming increasingly global. Universities are confronting stresses associated with rapid growth and with increasing demands by a wider, more diverse range of stakeholders.*

Findings from studies sponsored by the National Science Board; as well as studies by other organizations, reveal growing pressure on research and graduate education due to the expanding demands on universities. These demands have been accompanied by rising costs, budget constraints on traditional sources of funds, globalization of advanced education, and the need to adapt the rapidly changing-almost too rapidly changing-technologies in order to educate students at the cutting edge of science. We have been hearing a rising chorus of criticisms from employers of Ph.D. graduates, from students themselves, and from the public. These include the narrowness of the curriculum and the experience provided by Ph.D. programs, the unresponsiveness of universities to the needs of the workforce, the lengthening of time to

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3. V. Bush, *Science, the endless frontier, 40th anniversary ed.* (Washington, DC: National Science Foundation, 1990; original work published 1945).

degree, the large number of foreign students in our graduate programs, and the low participation by some domestic minority groups in science and engineering degree programs and on our faculties. There are further complaints concerning the inaccessibility of research faculty to their students and the lack of guidance to graduate students on realistic future careers. There is, finally, the suspicion that time to degree for some graduate and postdoctoral students is prolonged not to benefit their education, but rather to provide a source of cheap labor for their faculty advisors.

Amid these complaints, the faculty-centered model for graduate education also places enormous stress on faculty. Graduate education is essentially an apprenticeship that can demand substantial faculty time and personal involvement. Frequently it also involves responsibility for obtaining support for the student through the faculty member's research program. Growing demands for accountability by the federal government and university administrations, and increasing competition for research dollars eat into faculty research time, leaving even less time to devote to mentoring and to teaching. We also hear increasing complaints about the federal role in the partnership with universities, and the sense that federal support has become undependable. Uncertainties in funding increase pressures on faculty members and students alike, as research projects on which doctoral candidates rely for thesis support are threatened or actually interrupted due to the vagaries of the federal funding environment.

In the interest of improving outcomes for NSF support, the Board in 1995 charged its Task Force on Graduate and Postdoctoral Education to examine the effectiveness of NSF's mix of support modes for graduate and postdoctoral students-fellowships, research and teaching assistantships, and traineeships. The Task Force concluded that available data were inadequate to measure the relative effectiveness of different support modes. It therefore recommended development of additional databases and experiments in graduate student support in order to address the data needs.

In The Federal Role in Science and Engineering Graduate and Postdoctoral Education,[4] *the Board identifies several areas for improvement in the partnership while re-affirming the critical role offederal support for graduate education and its benefits to the nation. These recommendations address (1) federal policies and processes that inadvertently undermine federal objectives for funding research and education at academic institutions, (2) the need for federal encouragement of institutional and faculty efforts to develop innovative programs that broaden guidance for student career decisions, and (3) the need to promote more effectively diversity in graduate education by identifying and encouraging promising students earlier in their educational careers. The Board, in addition, urged universities to reassess their criteria for admission and support for graduate students and to improve integration for postdoctoral students into their campus communities.*

The partnership between the federal government and the academic sector has more than met the promise outlined by Vannevar Bush and has become the model for graduate education in other countries. But. . . today, it is fair to say that the federal government as a whole does not have a

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[4] National Science Board, *The federal role in science and engineering graduate and postdoctoral education* (NSB 97-235; available at *http://www.nsf.gov/nsb/documents/start.htm*).

good grasp of the impact of its policies and programs for supporting academic research in education. Efforts are now underway in both the Administration and the Congress to come to grips with the federal role in education, in the context of the compact between the federal government and universities.

Questions on the federal role that we need to address include, Do current federal programs and procedures serve to encourage the production of highly able scientists and engineers in sufficient numbers and with appropriate training to meet national needs for the science and engineering workforce? Could the underrepresentation of some groups in science and engineering be addressed more effectively through the federal-university partnership? Should federal policies be directed to decreasing time to degree? Since over three-quarters of Ph.D. recipients are not employed in research universities, does federal support encourage participation of graduates for career opportunities outside the research university environment as well as for faculty positions in research universities? Do federal programs and policies for support of research in universities enrich the learning environment and support free and open inquiry? Or, does federal support tend to encourage narrow specialization in areas related to the immediate needs of mission agencies or faculty members? Is synergy among researchers in different fields, academic institutions and sectors encouraged by current federal policies and programs?

I look forward to learning from the ongoing, wide-ranging innovations in the academic sector that are represented here today. Each is a separate experiment. But in total they reflect our highly diverse system of education that, in partnership with the federal government, U.S. industry, and others, has produced the most successful enterprise in history for educating scientists and engineers. Our science and technology enterprise today represents the intellect, imagination, and energy that can continue to enrich our educational systems and the lives of all Americans for the coming century. We cannot rest on the remarkable successes of this enterprise. But I would not suggest either that we abandon the logic of the Bush proposal that has served the science and the nation so well. Rather we should reaffirm and enhance that vision, We should build on our experience at supporting the highest levels of human intellectual achievement in an environment of free and open inquiry, which is the path both to advancement and knowledge and to an ever improving quality of life for our nation and for humanity.

Moderated Discussion among Representative Stakeholders

Clifton Conrad, ***Professor of Higher Education, University of Wisconsin-Madison (Moderator)***
Roger Geiger, ***Professor of Higher Education, Pennsylvania State University***
Martha Krebs, ***Director of the Office of Energy Research, U.S. Department of Energy***
Jules LaPidus, ***President, Council of Graduate Schools***
Robert Lichter, ***Executive Director, Camille and Henry Dreyfus Foundation***
Grover Owens, ***Senior Manager of Doctoral Recruiting Corporate Research Division, Proctor and Gamble***

At the opening panel of the Graduate Education Forum, speakers representing higher education, business and industry, government, and professional organizatidns laid the groundwork for

discussion during the two-day conference. A diverse set of speakers was invited to the opening session to discuss perspectives on the major forces for change, the challenges, and the opportunities facing graduate education today. Opening session speakers presented information on the recent history of graduate education, citing reports such as the 1995 COSEPUP Report' and Roger Geiger's paper for this **Forum.**[6] They also presented a variety of current data on graduate education such as student demographics, graduation rates, and employment rates in academia and industry-depicting trends and identifying main issues. Panelists highlighted the economic, political, technological, and societal pressures affecting graduate education today. They presented their observations on the current status of graduate education, stating their views on the system's strengths and weaknesses and offering suggestions and strategies for reform. They also spoke of the future of graduate education, noting that change-in what they described as a relatively successful system-would be both complex and difficult.

Roger Geiger provided context for the session by discussing a model, and its key aspects, for viewing the past, present, and future of graduate education. He referred to the last 25 years as the "old era of graduate education," characterized by the overproduction of **Ph.D.s,** a diminishing number of available academic positions, and an imbalance in the levels of recruitment, application, and acceptance of graduate students. He noted that the difficulties of this "era" have been discussed for a quarter of a century, with national studies of these problems going back at least to the reports of the National Board on Graduate Education published from 1972 to 1976, that are echoed in the 1995 COSEPUP Report. Geiger thinks that the patterns of change in graduate education are complex, but are having little impact on the fundamental characteristics of the system: departmental control, the qualitative imperative, a highly efficient national market, and externally sponsored research. He portrayed the current strength of the graduate education system as a legacy of this "old era," but cautioned the audience that this inherited strength is also exactly what makes graduate education difficult to change. Change, he said, is needed as the graduate education system possibly faces a "new era" and new challenges in an increasingly complex world.

Geiger noted "two dynamics of change that are inherent in the current situation." The first is the changing face of research in graduate education, which features more and more research conducted in specialized units. The second is the rising power of students, who use their favorable bargaining positions (a result of increasing competition for the very best graduate students) to demand placement in innovative programs, thus facilitating the growth of such enterprises. In speaking of the future of graduate education he referred to futurists' predictions of an emerging "knowledge society." He asserted that in order to become part of the "knowledge society" the graduate education community must shed the psychology of the "old era," more broadly train doctoral students to serve society, and adopt a new "growth psychology" which preserves the "enthusiasm for the growth of knowledge" into these emerging circumstances. He maintained that only then would graduate education experience "a rejuvenation."

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5. See note 1 above.

6. R. Geiger, ***The old era in American graduate education*** (Madison: University of Wisconsin-Madison, National Institute for Science Education, 1998).

Martha Krebs, representing the federal government's interests in graduate research and education, expressed support for training the next generation of scientists and engineers. She explained the Department of Energy (DoE) mission: to promote national security, energy, technology, environmental cleanup, and science. She described the dependence of the agency on science and technology, explaining that the agency must utilize the latest innovations and understand the fusion of science and technology across disciplines to fulfill its mission. She emphasized that new combinations of technology and science are driven by the need to be responsive to the increasingly global character of the marketplaces in which industry and government interact. Similarly, the need for such interdisciplinary expertise translates into the desire to hire graduates with the kind of broad training that prepares them to work in this internationally diverse, interdisciplinary professional environment. In turn, these needs define the government's interests in graduate education and multidisciplinary research and drive the strategy for government investment.

Robert Lichter spoke from his experience as a faculty member, an administrator in research and graduate studies programs, a foundation director, and an active advocate of science education reform. He asserted that, while the underlying drivers of change in graduate education are not always clear, the importance of engaging faculty and students in any change effort is essential to its success. He advocated changes that would both ensure faculty buy-in and broaden graduate students' experiences. For example, he suggested developing student's professional skills in management and communication, while maintaining the emphasis on research in the doctoral training experience. However, he also expressed concern that the proliferation of professional master's programs, which concentrate on training rather than research, would take graduate education down the path to "careerism." He acknowledged that graduate education must address multiple expectations from multiple parties and must also address the diverse needs of an increasingly multicultural, mature, and international graduate student population. He suggested that the featured practices at the Forum provide good examples of how to address the needs of various stakeholders and "allow multiple pathways for Ph.D.s to put skills into useful practice."

Lichter closed his remarks by reminding the audience that, while the drive for multidisciplinary education is important, the graduate education community must not lose sight of the fact that "new disciplines have been derived from expertise in an existing discipline." In a similar fashion, he stated that change in graduate education must be built on the core disciplines and the issue is "not to fix a bad system, but to make a good system better."

Jules LaPidas presented a critique of graduate education and framed considerations for the future of the system. He argued that the basic issues important to graduate education have not changed over the last century and that the defining principles of graduate education should not change in the future. Yet he noted that change is undeniably inherent in the graduate education environment-to be found in the constantly changing knowledge base, the shifting context of a continuously changing world, and the introduction of new policies and practice.

LaPidas reflected on several issues already influencing change in graduate education. He called attention to the unpredictability of forecasting such trends as faculty shortages and changing student demographics. He spoke about the dilemma of encouraging students to aspire to a

graduate degree despite the uncertainty of the current job market. He wondered about student education and career expectations and what the responsibility of the graduate institution should be in addressing those expectations. He spoke of his belief that graduate education is more about knowledge than information and more about scholarship than research. He suggested that the apprenticeship model of graduate education needs to be replaced with a model that is driven by the educational needs of the student rather than the research needs of the faculty. He also pondered how graduate institutions would respond to the changing academic job market, globalization, and changing industrial research needs. He characterized these issues as major challenges and as major opportunities facing graduate education in the next century.

In speaking of the future of graduate education, LaPidas reiterated that the primary purpose of universities is to advance research as well as learning. He noted that the context in which that will be accomplished in the future is almost certain to change-universities, as they are now constituted, will no longer exist. Universities as institutions may shrink, grow, or remain static, but they will undoubtedly continue to broaden the research enterprise by working with industry, incorporating new technology, developing interdisciplinary graduate programs, and serving an increasingly diverse student population. LaPidas shared his thoughts about the major changes in store for universities and challenged the entire graduate education community to not only become more receptive to change, but seek change so that universities can continue being "places where faculty and students seek knowledge together."

Grover Owens rounded out the panel by representing the voice and interests of business and industry in graduate education. In delivering what he called "the message from industry," Owens agreed with the other panelists that the graduate education system is not broken. He assured the audience that, from industry's perspective, the system needs "only minor improvements" and "evolutionary, rather than revolutionary" changes. He confirmed that, in general, graduate education is producing the breadth and depth of graduates that industry needs. He suggested that graduate education should not model its programs based on unpredictable job market projections and should not discourage student aspirations to attain doctorate degrees, because despite the fluctuations in the job market, industry continues to be interested in hiring qualified Ph.D.s. He encouraged the audience to consider increasing interactions with industry in the form of partnerships, student industry internships, industrial seminar series, and faculty industrial sabbaticals. He noted that preparing graduate students with professional presentation and writing skills would go a long way toward meeting industry needs and ensuring graduate placements. He suggested that, as industrial research and products become more and more complex, it would be advantageous for academia to respond by offering graduate students more multidisciplinary program opportunities. He closed by encouraging the graduate education community to conduct outreach and education with the K-12 community to facilitate local connections and foster future graduate students.

The panelists urged the audience to reexamine the interface between graduate education and industry, to reflect on the current tension between research and educational interests, and to reconsider the role of administration, faculty, graduate students, and postdoctoral fellows in graduate education institutions across the country.

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Panel on Strategies for Change in Serving Educational Infrastructure

Jan Smith, ***Co-Director, University of Minnesota Center-for Teaching and Learning Services and Program Director, Minnesota Preparing Future Faculty (Moderator)*** (see *DPSC*, pp.178-179)

Timothy Donohue, ***Professor of Bacteriology, Director of the Biotechnology Training Grant, University of Wisconsin-Madison*** (see *DPSC*, pp.134-138)

Jody Nyquist, ***Assistant Dean in the Graduate School and Director of the Centerfor Instructional Development and Research, University of Washington***

Irelene Ricks, ***Grants Administrator, Howard University Graduate School of Arts and Sciences*** (see *DPSC*, pp. 174-177)

Stacy Lane Tice, ***Assistant Dean of the Graduate School, Syracuse University*** (see *DPSC*, pp.146-152)

The second panel focused on the strategies, obstacles, and lessons learned by those who have begun to implement innovative programs and address changes in the educational infrastructure at their respective institutions.

From her experience developing programs and strategies to prepare graduate students to teach as TAs and future faculty, Jody Nyquist spoke of the significance of institutional policy that supports and nurtures such innovative programs. She emphasized the University of Washington's efforts to support interdisciplinary Ph.D. programs, fund teaching fellowships in which graduate students work with faculty mentors to create new teaching products, and develop an in-depth program review process for TA preparation programs.

Stacey Lane Tice highlighted her involvement with the ***TA Program***, the ***Future Professoriate Project*** (FPP), and the ***Preparing Future Faculty*** (PFF) programs at Syracuse University. She spoke of the evolution of these programs from early start-up to institutionalization, concentrating her comments on the start-up stage of development. She noted the tendency for graduate institutions to be decentralized, a status that can inhibit change and innovation. To counteract the effects of decentralization, she suggested incorporating key faculty in change initiatives and carefully addressing departmental politics and institutional culture. She conveyed the message that start-up was perhaps the most challenging stage of any change initiative and recommended that others start small, work with motivated departments with a successful track record, engage interested faculty and graduate students, and build on strengths to facilitate positive change.

Jan Smith presented a similar story about the development of the University of Minnesota ***Preparing Future Faculty*** program. She urged the audience to create quality programs. Sustainability depends on gaining both financial and program support from chairs, deans, and provosts and ensuring that students and faculty are satisfied. She noted that to successfully institutionalize a program you need to operate in a manner that anticipates the next phase, position the program to withstand organizational shifts, and work to secure funding in the regular budget.

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Irelene Ricks featured the fusion of Howard University's PFF program (which emphasizes development of teaching) with its Department of Education-sponsored ***Graduate Assistants in Areas of National Need*** project (which emphasizes research in science and math). In the resulting program, science and math faculty conduct research with student fellows in the lab and help develop pedagogical skills in those fellows for teaching positions. The integration of these two programs has proven to be successful, serving the needs of both students and faculty.

Timothy Donohue presented his perspective of change in graduate education framed by his role as director of an NM-sponsored predoctoral Biotechnology Training Program. He described the evolution of this decade-old, nontraditional, cross-disciplinary program in which motivated faculty and graduate students at the University of Wisconsin-Madison sought out creative solutions that "pushed the envelope of what was already in place on campus." The laboratory rotations, seminar series, summer industrial internships, and other features of the program provide an example of what Owens had referred to as evolutionary, rather than revolutionary, change. Donohue encouraged participants to use existing institutional resources and tap into federal funding that encourages development of innovative approaches to education. He also emphasized the need to work within and build on current institutional structure, policy, and culture.

Speakers encouraged the audience to develop graduate programs that address the career needs of all students (careers in academia, business/industry, and government) and to promote interdisciplinary programs. They discussed specific programs, giving as examples the proliferation and success of Teaching Assistant programs, PFF programs, cross-disciplinary programs, industrial internship programs, and others which incorporate these traits. Finally, speakers suggested that, from start-up to institutionalization, developers should keep their eye on the future and strive to establish programs that build commitment with students, faculty, and administration.

Panel on Strategies for Change in Serving Students and Society

Chris Golde, ***Assistant Professor of Educational Administration, University of Wisconsin-Madison (Moderator)***

Lisa Brandes, ***Director of the McDougal Graduate Student Center, Yale University*** *(see DPSC,* pp. 43-47)

Paula Cohen, ***Developmental and Molecular Biology Instructor, Albert Einstein College of Medicine*** *(see DPSC,* pp. 54-59)

Brian Schwartz, ***Professor of Physics, Brooklyn College of the City University of New York*** *(see DPSC,* p. 53)

Debra Stewart, ***Vice Provost and Dean of the Graduate School, North Carolina State University*** *(see DPSC,* pp. 126-128, 158-163, and 187)

Orlando Taylor, ***Dean and Professor in the School of Communications, Howard University Graduate School of Arts and Sciences*** *(see DPSC,* pp. 48-52)

Speakers contributing to this discussion represented promising practices and programs that share the explicit goal of serving students and society. Debra Stewart presented a set of Operating Principles for those considering implementing such innovative programs. She advocated a balance between maintaining stability and promoting change, valuing traditions while fostering innovations, enforcing policies and procedures while remaining flexible to new ways of doing things, and, finally, exercising power while simultaneously empowering students and faculty.

Paula Cohen spoke of the special needs of postdoctoral trainees, in particular mentioning their need for additional career support and mentoring. She described a collaborative effort between faculty and postdoctoral fellows that was formed at Einstein College to address these needs. The project was a grassroots effort begun by a group of disenfranchised postdoctorates who, as a result of a survey of postdoctorates across the campus, worked with faculty to alleviate common problems and improve policies through the establishment of an Association for Postdoctoral Fellows.

Lisa Brandes explained the Yale University effort to counteract the decentralized structure of the graduate school by establishing centralized support and career services, interdisciplinary programs and industry partnerships. She explained that these efforts were a "community building exercise" and were made possible by the convergence of student involvement, administrative vision, alumni support and financial resources.

Brian Schwartz used data to illustrate the history of Ph.D. job placement trends. He showed recurring problems and inconsistencies, in particular drawing attention to the imbalance between the current number of Ph.D.s and available academic jobs. He closed by discussing an NSF program designed to enhance the employment opportunities of Ph.D.s in science that features non-credit courses in career development, communication and business skills.

Orlando Taylor spoke from the perspective of historically black colleges and research institutions, but emphasized that his concerns were applicable to all graduate institutions. He suggested four areas or strategies for change in meeting the needs of society and students:

First, improving the criteria for judging talent and the likely success of potential students. Second, transforming the graduate environment paradigm from a "hazing" to a nurturing environment. Third, reforming how we teach to enhance the development of communication skills, critical thinking, and working in teams. And fourth, developing better strategies for gauging the pulse of the needs of all the people.

Panel on Strategies for Change in Serving Business and Industry

Bernice Bass de Martinez, ***Senior Associate Vice Presidentfor Academic Affairs and Dean of the School of Graduate Studies, Indiana State University*** [see DPSC, pp. 112-l 17]

Edwin House, ***Dean - Office of Research, Director of Hazardous Waste Management, Idaho State University*** [see DPSC, pp. 94-102]

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Lynn Melton, ***Professor of Chemistry, Director of the Chemistry Doctoral Program, University of Texas-Dallas [see DPSC,*** pp. 74-79]

Fadil Santosa, ***Associate Director, Minnesota Center for Industrial Mathematics and Associate Director of Industrial Programs, Institute for Mathematics and its Application, University of Minnesota [see DPSC,*** p. 125]

Scott **Sewall**, ***Academic Administrator, Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology [see DPSC,*** pp. 118-124]

The last panel discussion focused on how to better prepare students for the transition into careers in business and industry. **Bernice** Bass de Martinez expressed her belief that continued success and survival of graduate education will depend on listening to **alumni** and to those in business and industry. She warned the audience of the increase in for-profit universities that provide professional development for business and industry and that are receiving an increasing share of the funding pie. She predicted that the flow of funds from **business** and industry will cease unless graduate education institutions respond to the needs of these external constituents by preparing graduates with technology, communication, and business skills. She challenged participants to be more customer driven and respond to the demands of students and employers in business and industry.

Edwin House spoke of a successful interdisciplinary master's program in the state of Idaho, designed to meet the engineering needs of industry. He related that the strength of the program is built on a two-way partnership between industry and faculty, with each partner having "equal interests and common interests." Industry needs are expressed to a "centralized council of representation," curriculum is continually updated to meet industry needs, and an industry advisory council provides feedback on student and graduate performance. Interested faculty develop research partners in industry through interaction with the Idaho National Lab.

Scott **Sewall** presented a different industrial professional master/s degree program that prepares students for upper-level management careers in technical consulting fields. The program is based on a broad curriculum that integrates physics, math, and chemistry and that addresses industry's need for applied scientists well-versed in business, technical, and communication skills. The creation of this degree program was motivated by a perceived "gap" between the usual degree programs in the geological sciences and some of the emerging needs of industry.

Fadil Santosa described an industrial program offered in conjunction with the Institute of Mathematics Center Application (an NSF funded institute) and the Minnesota Center for Industrial Mathematics. The program encourages interaction of research and education that involves industrial problems in mathematics. Students may acquire a master's or doctoral degree in Industrial Mathematics. The program has elements of a solid mainstream mathematics degree but also features an ongoing industrial problem seminar, industry speakers, an industry math modeling workshop, and an internship in industry for each student. The program was started to offer students the chance for nontraditional careers in mathematics. It grew from the vision of a few and with support from the university to offer new courses. Santosa described the program as a "win-win situation" for all: students gain skills and exposure to industry, industry gains

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employees with applied research experiences, and faculty get a chance to work on new kinds of problems.

Lynn Melton presented the Doctor of Chemistry program at the University of Texas at Dallas, a program introduced in 1989 with students and society in mind. Planning for the program began in the mid-1970s in response to expressed needs in the chemical and pharmaceutical industries that traditional master's and Ph.D. programs did not satisfy. The program has a mandatory industry internship and is designed to "intentionally prepare industrial problem solvers." Melton noted,

We believe that you can design a program that delivers students from a bachelor's degree in chemistry to a career position in chemistry in five years, no postdoc.

This program has a 100% placement rate for industry practicum students and Ph.D.s in industrial R&D, chemistry support, and manufacturing positions. The strength of the program is that it prepares students to obtain and be successful in chemistry careers in industry.

Responses from the Forum

The Current Status of Graduate Education

As Roger and others have mentioned here, we are talking about a system that has been regarded for some time as the premier system in the world. What we are talking about is the need to change it. And I would argue that, from one point of view, change is absolutely inherent in any concept of graduate education. What graduate education deals with, certainly more than any other part of higher education, is a constantly changing knowledge base, a constantly changing world in which what we know tends to define what we do not know, and that process continues on and on. Jules LaPidas

The issue is not to fix a bad system but to make a good system better and more meaningful for the students, the faculty, institutions, and postgraduate settings. Robert Lichter

Hope arises because we have a conviction that we can make choices, that our choices can make a positive change for our shared future. Choice means facing risk. Risk requires letting go as well as holding on, and it's inevitable. This Forum is about ensuring the future of science and technology through our research institutions. You are in the group of risk takers and those who will make choices. Martha Krebs

Many Forum participants felt compelled to write in response to the comments made by panelists about the status of graduate education today. Most reacted positively to the assertion made by LaPidas that "graduate education is not broken, but is in need of renewal." In particular, participants generally agreed with the speakers' premise that the fundamental principles of U.S. graduate education should remain unchanged, and voiced support for a system with a long-

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standing international reputation for providing scholarly education and producing superb Ph.D.s. At the same time, most were receptive to the suggestions for a "new emphasis," agreeing with Robert Lichter that the task is to make "a good system better." In short, they liked Owen's concept of "evolutionary, not revolutionary" change and agreed that incremental change that builds on the core foundation of an established system is the preferred path to improving graduate education. One Forum participant summarized the thoughts of many in his reaction to Jules LaPidas' remarks:

> I agree with Jules LaPidas that the principles of graduate education should remain unchanged—education rather than training, knowledge rather than information. But having said that, there is a need to address what happens after the dissertation is written and the student has graduated.

A few felt that the panel discussion of the current state of graduate education was "conservative" and failed to fully address the system's shortcomings or confront the sweeping worldwide changes that are putting pressure on graduate education to change. For example, Paul D. Nelson and Lowell Anderson expressed their disappointment with the opening session:

> This morning's presentations presented the expected cliches and self-congratulatory pronouncements that were smoothing and crowd-pleasing and avoided any explicit considerations of the forces for change that are at work in higher education. (Nelson)

> This was a seriously conservative introduction for looking at graduate education. . . . It smacked of American egocentrism and elitism. It failed to recognize the concerns of the global community and changing dynamics of the workplace. It reverted again to historical arguments-very meaningless—about training, education, careerism and job seeking. . . . If we are to change, we will need to look at organizational restructuring, advancing communication technology, and the rapidly changing role of the "University Market." (Anderson)

These think piece writers noted that for the graduate education system to remain viable, dramatic and comprehensive changes will be needed. A few felt that such change is inevitable due to the mounting pressures from institutional budget cuts, technological advances, student demands, global market changes in business and industry, and public concerns.

Other writers expressed the belief that graduate education is inherently resistant to change and were not optimistic about widespread improvements. They were struck by how little has changed in the last twenty years, citing an inertia due to "rigid institutional structures" and entrenched cultural norms. Some wrote that the decentralized organizational structure of graduate programs tends to isolate progress and make change difficult. Others criticized the prevailing institutional culture of graduate education by writing about faculty and administrators who have an "if it isn't broken, don't fix it" attitude, or who operate with an elitist attitude that places institutional and faculty prestige above the educational needs of students:

> The overwhelming message pointed to the need for "minor" changes to the system rather than a complete overhaul. But with the huge amount of inertia present in graduate education, and a "don't fix what isn't broken" attitude, even "minor" changes can be difficult to implement. (Jim Freericks)

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Several writers noted the need for an overarching "mission," "common direction," or "comprehensive vision" for graduate education that transcends individual institutions. As one participant wrote: "There is a need for common graduate education strategies among stakeholders (i.e., government agencies, academe)." In his think piece, Jules LaPidas also stressed this point:

There will be strong pressures to change the nature of graduate education in science and engineering to respond to short-term fluctuations in both academic and industrial sectors. To avoid succumbing to these pressures, faculties, students, and institutional administrators need to articulate a shared vision of the elements and principles that define graduate education and ensure that those concepts that provide the context for change and innovation not only are encouraged, but are seen as essential.

While a common mission was advocated by a few, others felt that it should not constrain institutions to a single goal for graduate education:

> One problem the system has is that there is one perceived path to success. If we are not careful we could wind up replacing this single path with just one or two other paths. . . . A better strategy would be to remove barriers hindering students from finding their own paths. (Kevin Aylesworth)

> Graduate education should be viewed as a golden key-remember a key is much more useful if it opens numerous doors, not just one. (Maribeth Watwood)

Despite the divergence of opinions about the current state of graduate education and the lack of consensus about its future direction, virtually all writers agreed that at least some change is needed and is inevitable. Many agreed that a broad vision of the future should guide the actions of graduate education institutions and that coming together to learn about promising practices and strategies for implementation was a constructive start to developing that direction. In her presentation, Debra Stewart spoke of such a vision of the future:

In our experience over the last several years at North Carolina State, we have developed what we quite immodestly call "the new paradigm for graduate education." The new paradigm is really not just one thing. It is processes and programs and opportunities for students; for faculty, it's resources, it's ideas, it's options for action; and for all of our stakeholders, it's a way of participating and shaping graduate education to ensure that its product-the graduate-is as well-prepared as he or she can possibly be for the next century.

The Current System: Issues to Consider

Supply and Demand: Labor Market Changes

With the continued change in the job market at the beginning of this decade, graduate education and the graduate establishment came under attack for encouraging people to go on to graduate school, because there were no jobs. [We were criticized] for misleading people. And some have talked today about our need to be more realistic about what the job market is. But we are caught

again on the horns of a dilemma: Do we encourage people to go on, telling them that they may not get the jobs they think they are going to get? I believe that it is always good public policy to encourage people to aspire, particularly to more education, and I think that we have to continue to do it. Jules LaPidas

A majority of participants commented on the change in the academic job market for Ph.D.s. Few were surprised by the panelists' recitation of the data that outlined the current mismatch between the number of Ph.D.s prepared for positions in academia and the decline in available academic positions. Some of these writers also expressed concern that many faculty are not addressing the problem. Rather, the faculty seem to still be focused on preparing graduates exclusively to assume academic positions:

> Faculty trained several decades ago still advise students as though the only appropriate career is to reproduce themselves (academic setting, teaching and research). It's difficult to convince them that students with other/industrial career aspirations are not failures. From an administrative viewpoint, it's hard to dictate change of attitude in this area

> Our market has segmented into at least two areas (academic and industry) that have vastly different requirements, and yet we continue to teach Ph.D.s in the same way. Our MS programs have done a much better job of adjusting to the market and 'emerging areas. The problem is that we look at the Ph.D. as a single product, leading to the necessary conclusion that the product will serve one segment and not the other. Given that we grant Ph.D.s from universities rather than from industry, it is pretty clear which market will be served. (Steve Markham)

> At our institution, many programs have adapted to the changing demands placed upon them by the job market. However, we have encountered a "'defense mentality," as mentioned in the panel discussion, among many of our doctoral graduate faculty against making many of the changes suggested by the panel (multidisciplinary programs, industrial internships, Preparing Future Faculty, etc.). We clearly have a selling job ahead of us in regard to some programs. Our master's programs are more adaptable, as one might expect, but the doctorals are more resistant to change.

Another writer summarized the viewpoint of many that preparing future academics will require a new approach: "The academic job market has changed dramatically, and students need more help to go after fewer jobs." Other writers commented about the decline in the academic job market and advocated that the graduate education community respond by preparing graduates for alternative careers in business, industry, and government.

> We have learned that only a small fraction of graduate students become teachers and scholars. Making better teachers and scholars is good (ed course), but in an era of oversupply, the focus should be on preparing graduate students more appropriately for their diverse professional futures. (Bo Hammer)

> This rise in the pursuit [by graduates] of nonacademic, nonbasic research jobs like policy, management, sales, etc., is both well known and argues in favor of a Ph.D. curriculum that takes these options into consideration. (Robert Rich)

> Educate the faculty regarding the realities of the job market, the graduate student experience, etc. Find ways to help faculty assume responsibility for **mentoring**, counseling, advising, and nurturing students and their learning.

Some were comfortable with the idea that changes in graduate education are spurred by the inevitable evolution of the economy and job market: "Those areas that require change are being compelled by market forces to evolve" (Robert E. Thach). As Robert Kelly wrote, pressure from a new global labor market may result in positive change: " 'Let the market prevail' may be a useful paradigm for change that prepares students for evolving careers in science and engineering."

The unpredictability of the labor market and, in particular, the uncertainty of forecasting opportunities for Ph.D.s in academic or industry positions were also concerns of a number of writers. Brian Schwartz warned that "one can't make good predictions of the future and thus care should be taken with respect to giving advice or doing planning, be it for graduate schools, faculty, or students."

***DPSC* citations**

Career Services for Doctoral Students in Science and Engineering - University of Pennsylvania (*DPSC*, pp. 1-6) "University of Pennsylvania Career Services has a long-standing commitment to career planning for graduate students. Faculty members seeking to advance the career of their students may put the campus career center last on their list of resources, feeling that a "student service" could not possibly understand, let alone address, the needs of the students in their program. They need to be convinced that they can work effectively with the career center to help their students. At the University of Pennsylvania, overcoming this barrier has been accomplished primarily by delivering good service over a period of years."

Career Information Services – Sloan Foundation (*DPSC*, pp. 7-8) "With the help of the Alfred. P. Sloan Foundation, eleven professional societies are developing a set of materials aimed at providing students with career information. Unified around nine highly interactive CD-ROMs, the materials include brochures, videotapes, and World Wide Web pages as well as the CD-ROMs."

Master's in Science and Technology Commercialization – University of Texas at Austin (*DPSC*, pp. 38-42) "The IC2 Institute at the University of Texas at Austin and the Instituto Superior Tecnico of Lisbon, Portugal, are engaged in a cooperative experiment to provide groups of international students in Lisbon and in the U.S. a virtual, global, team learning experience in the commercialization of science and technology."

Doctor of Chemistry – University of Texas at Dallas (*DPSC* pp. 74-79) "The Doctor of Chemistry (DChem) Program is a highly effective means of preparing students for careers as 'industrial problem solvers,' i.e., doctoral level chemists who respond to short and medium term problems in the chemical industry. . . . The DChem Program was designed after the UT-Dallas

chemistry faculty had asked industrial contacts to describe their jobs in industry. . . . The intense two years, the experience gained in the Industrial Practicum, and the overall DChem program structure and student quality have made the students' movement into career industrial positions exceptional."

Industry Linkages: Partnerships and Global Connections

View your external partners not only as enablers but also as agents of change. The external partners in particular that I am referring to here are our industrial partners. We all know that they are wonderful enablers of change, and in a place like North Carolina State, they have funded us very generously. But we need also to see them as agents of change, as stakeholders who have lots of terrific ideas about the content of the business that we are in, not simply the process offunding it. Debra Stewart

We ask that you consider increasing industrial interaction. . . . And some of the things that we might suggest involve industrial interaction during the graduate program itself [such as] internships in industry. . . . I know that professors have a real concern about taking too much time away from the dissertation research, but from our point of view even one summer internship is a great opportunity to provide a viewpoint of industry and to get people more information on the career choices that they face. Another practical suggestion might be industrial scientific participation in seminar series. . . . Finally, industrial sabbaticals are something that, depending on our needs, we are supportive of and that we would suggest you consider to give faculty a better viewpoint of what goes on inside of industry and research that's there. Grover Owens

Another characteristic of the whole is the increasingly global character of the marketplaces in which industries and our graduates will have to work. Martha Krebs

The first thing I would like to say is that, if you think that this can be done in the old fashioned way of the university community telling industry what they need, it doesn't work. If you think that industry can tell the university what they should do, it doesn't work. What works at all levels in this effort is to be partners. And "partners" means the following: We have equal interest, and we have common interests. Edwin House

Many wrote of the weak connections graduate education institutions have with the "real world," noting the need for change:

> There is a need for a more global perspective in graduate science and engineering education: social sensitivity, language skills, global economy, and political awareness.
>
> Global markets: our graduate students must be comfortable with intellectual and cultural diversity. (Martin Cadwallader)

> Global implies being willing to set aside our point of view in order to appreciate, and benefit from, other perspectives. (Lisa Ruiz-Cardona)

> Change is definitely needed, especially in view of the global community of research made possible by the Internet. The demands on scientists (at research universities and in industry) are changing and will change in the next century, and graduate education should anticipate this and prepare for change. **(Leonie Boshoff-Mostert)**

For example, Charles E. Davis III wrote of the need to further develop partnerships and improve communication with industry:

> As graduate students funnel more and more into industry, clearer partnerships must develop to assist those students in making that bridge. . . . Industry seems to be able to clearly tell the university what it needs out of our students-we should listen carefully.

Writers expressed the need to improve communication channels with industry. Others agreed that better communication between industry and academia would serve to improve collaboration and partnerships:

> Industries are the second most important customer (next to students). They should speak out more on what their expectations are. (A. Ravindran)

> There is a considerable barrier between academia and industry. . . . Much more communication is needed between the two groups. (Donald Lewis)

> It would be helpful to get more industry feedback on current practices and useful innovations, perhaps divided into industries, different sizes of organizations, and regions of the U.S.

Other participants felt the lack of input from industry. One person wrote, "I would like to have more people from industry to speak to this issue. What are they seeking? What changes would they like to see in graduate education?" Another articulated this same concern and indicated interest in knowing "what works well for [industry] when forming partnerships, and what frustrates our potential partners."

During his panel presentation, Grover Owens polled the audience and found that there were only a handful of business and industry representatives present. The lack of industry representation spurred many Forum participants to comment further on the problems in developing more extensive collaborative partnerships:

> How does one get industry more directly involved in these discussions/meetings? Three out of 250-275 is not adequate representation. Yet it's clear that the NISE team made a concerted effort to try to attract industry folks.

> It brings me to wonder whether, despite the commitment to develop and improve graduate education in science and engineering, there is not still far more suspicion of industry and its power to pull academic science away from basic research and knowledge creation than can be productive for the future of graduate education in science and engineering.

Providing insight into why so few industry representatives were present, the following writers noted that industry-university partnerships pose challenges:

> There are tensions between academic and industrial objectives. These need to be articulated, debated, and, where possible, resolved. It will be important to have an array of industrial representatives, because the approach and attitudes are likely to vary. (Robert L. Lichter)

> The industrial/university partnership is one of the "hard-to-bring-abouts," depending on the institutional mentality and location. (Robert A. Jones)

> Our faculty support for research from industry is increasing. This necessitates the change in programs that get closer to industrial interests, which has both positive and negative connotations. Unless we manage this well, we can easily turn our universities into vocational schools. (Narayan Bhat)

Despite the challenges, many writers indicated that successful industry-university partnerships can and do occur:

> Recognizing and considering workforce (industry and government) needs and working with external organizations for funding do not have to contaminate academic value or research success. Internships that are well matched in academic/industrial/government interests/missions can (and do) result in win-win situations. Proprietary conflicts can be avoided.

Examples of how partnerships with industry could improve relations between graduate institutions and industry were provided by a few writers. They even noted how these partnerships could serve to improve the quality of graduate students' education and preparation for careers beyond academia.

> Our most recent efforts have been devoted to encouraging collaborations between faculty and industry to improve curricular enhancement discussions.

> A plus has been the emphasis on business partnership. When industry puts a premium on graduate education, it helps focus attention on graduate education and away from undergraduate or professional education. (Louis Terracio)

> I found the industry comments particularly interesting as one of my major responsibilities is to form and develop a program that includes infusing the industrial (at least nonacademic) viewpoint into the preparation of Ph.D. students in many disciplines. We are developing workshops, internships, and other activities to help expose Ph.D. students to nonacademic settings. (Thomas Callarman)

> To meet the need for student information on industry operations a course was introduced, taught by industry, on "Industry Practice." This includes organizational structure, regulations, operations, advancement as well as a mock interview. Thus, graduate education has been influenced by the changing environment evolving from research advancement and the industrial market for graduate students. (Thomas Yorio)

We also are working to expand contacts with and awareness of industry. A student-run organization, the Industry Roundtable, is sponsored through the UAB Graduate School. The need to continue to nurture and support these efforts was also underscored by several of the panelists. (Julia S. Austin)

DPSC **citations:**

Master's in Science and Technology Commercialization – University of Texas at Austin (*DPSC* pp. 38-42) [see p. 18]

Doctor of Chemistry – University of Texas at Dallas (*DPSC* pp. 74-79) [see p. 18]

GOALI – Louisiana State University (*DPSC* pp. 86–90) "LSU and Hewlett-Packard Laboratories, Palo Alto, recently completed an NSF GOALI-supported one-year collaboration involving research in magnetic materials. This program provided student support and travel to HP Labs and relevant scientific conferences, interactions that stimulated an exchange of ideas and technical capabilities and provided new opportunities for materials research and device applications."

Hazardous Waste Management Program – Idaho State University (*DPSC* pp. 94-102) "[This is] an interdisciplinary master's degree program in hazardous waste management featuring partnerships with industry, another university, and 4 colleges and 10 participating academic units within Idaho State University. The program features innovative approaches to provide incentives for faculty and departments to participate, regular input and consultation from industry to shape the curriculum, problem-solving techniques to address competing interests, and special approaches to quality control of the program."

Industrial Interdisciplinary Program – Virginia Polytechnic Institute & State University (*DPSC* pp. 103-106) "The Practice-Oriented Master's Degree (POMD) is a professional degree offered by the College of Engineering at Virginia Tech for engineers pursuing industrial careers .... We were motivated to develop the POMD program because we believe that the increased complexity of modern professional practice, coupled with an already overloaded four-year curriculum, has created the need for an extended educational experience to prepare engineers to function more effectively in the highly competitive global market."

A Ph.D. in Technology Management by Consortium - Indiana State University (*DPSC* pp. 112-117) "The Ph.D. in Technology Management, approved by the Indiana Commission for Higher Education on February 13, 1998, established a precedent for the advancement of graduate studies in technology. The mission of this program is to promote research through doctorate level studies addressing the explosion of new technologies and knowledge. . . . Primary features are . . . internships with business and industry providing opportunities for applied research."

Professional Master's Degree Program in Geosystems – Massachusetts Institute of Technology (*DPSC* pp. 118-124) "In the fall semester of 1997, the Department of Earth, Atmospheric and Planetary Sciences (EAPS) of the Massachusetts Institute of Technology

initiated a new degree program entitled Master of Science in Geosystems. This one-year course of study was specifically designed as a "first professional degree" with the goal of preparing students for scientific and management careers in the environmental, natural resource, and technical consulting industries by providing the scientific skills related to the observation, analysis, and simulation of complex natural systems. In constructing the program, input was solicited from industry representatives, and feedback was obtained regarding the appropriate educational objectives."

Programs for Industrial Mathematics – University of Minnesota (*DPSC* p. 125) "The School of Mathematics at the University of Minnesota with the Institute for Mathematics and Its Applications . . . offers several programs that provide training for students who wish to seek careers in business and industry."

Recruitment and Retention: The Best and the Brightest

The discussion of labor market changes and industry relations was related to a discussion of recruitment and retention issues. Some writers noted that many talented baccalaureate and master's degree students were choosing well-paying jobs in industry over high-cost graduate education. Some expressed the problem as an inability to attract and retain the "the best and brightest" students.

> One question that the panel failed to answer is, How do we attract the brightest students into the Ph.D. program? The job situation is so good, particularly in engineering and computer science, that this is a big problem, in spite of providing a challenging exposure to research to these students in their undergraduate program. (**Anant** Kukreti)

While writers acknowledged the difficulties with recruitment, they also wrote about countervailing efforts to deal with the problem and illustrated how some institutions are responding in positive ways to this challenge:

> I find myself challenged by the [fact that the] very same sponsors of graduate programs are constantly recruiting undergraduates upon graduation for industry positions. GEM is a consortium of colleges, universities, and industry promoting graduate education. I find fewer and fewer students are going to graduate school as careers [for people] with a bachelor's degree seem promising, especially in industry. Given the need to address demographics and diversity, GEM needs to change in order to change graduate education. Our new GROW program promises to address the changes needed in graduate education. (Doris Roman)

> Our department's problems with competition and recruiting have caused us to look to partnerships and dual-degree programs to attract the most qualified students. (Edwin Hahn)

> Our graduate program is threatened by the drop in the number of students pursuing advanced degrees in physics. We are approaching this problem by reconsidering our role in the educational **process**— we must provide students with the tools they need to succeed beyond academia. We approach this by promoting dual-degree opportunities, for example, Ph.D. Physics/MS Systems (Computer Science)

and by implementing a professional (read terminal) master's degree in Applied Physics. The latter involves a three-month internship in industry or at a national lab. (Richard Lutz)

DPSC **citations**

Dual Degree Programs in Veterinary Pathobiology – University of Illinois (*DPSC* pp. 9-13) "Members of the Department of Veterinary Pathobiology direct gradaute programs leading to the MS and Ph.D. degrees in microbiology, immunology, parasitology, epidemiology and molecular biology, as well as Ph.D. residencies in general pathology, toxicological pathology and laboratory animal medicine. . . . Significant expansion of departmental graduate programs has occurred in the development of specialized medical training leading to dual degrees. The dual degree programs attract high caliber students with an aptitude for experimental research."

Graduate Education Enhancement Program for Underrepresented Minority Students in the Computational Sciences – Rice University (*DPSC* pp. 16-23) "Since the fall of 1995, the Sloan Foundation has funded a graduate education enhancement program at Rice University that focuses on student retention through community building, counseling, intervention, mentoring, professional development, and student funding that has experienced dramatic success in the retention of underrepresented minority graduate students. . . . Even though recruitment is not sufficient to solve the underrepresentation problem, it is necessary. Retention as a solution assumes sensitive recruitment strategies and admission policies that admit a diverse group of students with a record that indicates potential for successful graduate studies. Recruitment too often means just competing for the precious few minorities that look excellent according to the traditional evaluation process."

Graduate Experience Project – University of Michigan (*DPSC* pp. 25-29) "In response to the underrepresentation of women in the sciences, the University of Michigan, in conjunction with the Sloan Foundation, has initiated a model recruitment and retention program for women graduate students in engineering and the physical sciences."

Biotechnology Training Program – University of Wisconsin-Madison (*DPSC* pp. 134-139) "The General Medical Sciences Institute of the National Institutes of Health and the University of Wisconsin-Madison are proud sponsors of an institutional predoctorate Biotechnology Training Program (BTP). The BTP seeks to educate a new cadre of cross-disciplinary scientists and engineers who integrate and apply concepts from the biological, physical, and computational arenas to biomedical research. . . . The BTP does not offer a Ph.D. degree; rather it coordinates training activities for students admitted to a variety of doctoral programs. . . . Interest in the BTP has increased steadily ; more than 5 high quality students apply for each available training grant position. There are also emerging signs that the BTP is attracting its own pool of high quality student applicants, since several students matriculate at UW-Madison each year specifically because of the BTP."

The Role of Research in Graduate Education

Let me argue that the principles of graduate education are things we should NOT be changing. And that of course depends on whether you agree with me about what the defining principles of graduate education are. I would say that graduate education has to be more about education than training, as Robert Lichter said. It has to be more about knowledge than information. And I believe very strongly that it has to be more about scholarship than research. I think those are things that should not change in graduate education, and that we should make very sure do not change by our insistent and consistent attention to them. Jules LaPidas

Many writers picked up on the panelists' reflections regarding the purpose of graduate education. Panelists spoke of conflicting purposes present in the current graduate system, highlighting the tension between "education vs. training," "knowledge vs. information," and "scholarship vs. research." In particular, they spoke of the tension between research and education that often manifests itself in faculty emphasizing research over education or scholarship. Forum think piece writers responded that the tendency for faculty to fulfill their own research agenda, often giving that precedence over the educational needs and interests of students, was a serious issue. Some blamed this imbalance between research and scholarship on the persistence of the apprenticeship model used widely in graduate education. Others criticized a tenure system that rewards excellence in research over teaching. Some expressed the need to improve student scholarship by teaching knowledge production, reinforcing professional skills, and matching research experiences to the student's interests. At the same time, a few expressed the fear that, rather than improving scholarship, changes in graduate education such as increasing applied research experiences, industry internships, and professional skills would result in less rigorous programs and would effectively transform graduate institutions into "trade schools."

Some advocated reform of graduate education by way of redefining the role of research in a student's graduate experience. They suggested a focus on the students' interests and their need to develop research skills and knowledge within, and across, disciplines to enhance scholarship and student learning. They also suggested that faculty shift to a mentoring model for teaching rather than the apprenticeship model.

There is one absolutely astounding change-which is often referred to as a cultural change—that I think we have great difficulty coming to grips with: the idea that. . . the driving force in graduate education should be the educational needs of the student rather than the research needs of the faculty. . . . [This idea] doesn't imply that the research interests of the faculty are not important, obviously. But [it challenges] the model of the research university in which the faculty do their own research and students are lucky to apprentice and be part of that research effort. What happens to those students afterward? What careers do those students see for themselves? Is the kind of education they get not particularly important, as long as they are having a good research experience and moving forward the research program of the faculty? That emphasis, I think, has to change. Jules LaPidas

Many agreed with the panelists that there was an imbalance between the faculty research agenda and students' educational interests and called for a reexamination of the role graduate students play as labor for faculty research projects:

For me, the most pertinent point was that made by Jules LaPidas: graduate education needs to change in order to focus on the educational needs of graduate students rather than on the research needs of faculty. I think a change in that direction will be profound, more revolutionary than evolutionary. It will affect admissions, classes, related education (like internships, teaching experience, career planning, advising, and mentoring) especially. Like the shift from teaching to learning, this will have profound effects. Chris Golde

> I agree with Eamon Kelly's point that graduate education needs to be rethought to get out from under the strict apprenticeship model. I thought Jules LaPidas reiterated this point with the suggestion to focus graduate education more on scholarship than research. This also implies that the focus of graduate education should be more tailored to the educational needs of the student rather than the research interests of the faculty. Graduate students' educational needs unquestionably include detailed research training and experience, but the motivation to attempt to fulfill that need should not originate from the view that they are cheap and malleable labor. (Leslie Lydell)

> Perhaps the two most interesting points I heard were (1) that the focus of graduate education should be the educational needs of the student and not the research needs of the professor and (2) the question of whether or not students have become a source of cheap labor for research.

> A key area to improve science education in the future is to convince faculty that requiring 60 hours per week in the laboratory working on a single protein is not the best way to prepare students for future careers. (Chris Gaj)

Some writers linked faculty reluctance to educate doctoral students for careers outside of academia with faculty interest in preserving the current research assistant role.

> In programs I've been acquainted with, there is a not-so-subtle indoctrination to the view that any position "less" than a tenure-track academic job is a failure. Feeding into this is the issue of graduate students as apprentices or as promoters of their supervisor's research programs. Two questions were raised, Does participation in the supervisor's research automatically lead to excellent training and education? Can we identify when the educational needs of the students are not being met by the research needs of the faculty?

> The role of a graduate program should be to prepare students to enter the workforce, attempting to keep in mind the realities of that workforce. Advisors should realize that their primary mission is to provide an education to their students, not simply to train their students to carry out needed tasks to advance the advisor's research aims. Many important programs that will enhance the future success of Ph.D. graduates in their future careers, such as teacher training and industry internships, could be more easily implemented in a more open climate.

While acknowledging that the educational needs of graduate students should be given greater attention, several writers warned the graduate education community to approach change with caution. They pointed out that the university's mission must not be sacrificed. The "quality" and "content" of graduate programs, "academic integrity," and "depth" of research must not be

compromised. Graduate programs must not be "diluted." They urged educators to preserve the quality of graduate education by maintaining scholarship and research integrity and to avoid turning graduate institutions into vocational or professional training schools by being overly responsive to the needs of industry.

We talk about graduate education but we often act as if we were engaged only in graduate training. Indeed that expression infuses the language of the discussion, and we run the risk of sliding into careerism. Robert Lichter

Others noted similar compelling reasons to be cautious when considering change:

> Research is and should be an integral part of a Ph.D. We do not want to weaken the research efforts of an institution or our nation. We have to keep this in mind as we approach faculty and administrators, because raising that issue is a common defense tactic. We need to get hard data on the fact that students who train more broadly still get their degrees in timely fashion and perhaps even contribute more to their department or institution. (Jennifer Miskowski)

> We need to be responsive to the needs of industry for educated graduates, but we are in the business of training/educating students on how ***to do*** research, i.e., in methodology and in the latest technical news and developments. Education is our business. We should keep this in mind. Training is for vocational institutions. (Gordon Melson)

> More professional people are demanding graduate degrees leading to specific technical degrees. I see faculty rebelling against these degrees, which typically involve little or no research. Universities don't want to become trade schools. How do we balance this? (Tiffany Barnes)

> We must guard against graduate programs becoming "trade school" programs in response to demands of industry and the legislature. We must clearly articulate to the public what graduate education is about. (Max C. Poole)

DPSC **citations**

Dual Degree Programs in Veterinary Pathobiology – University of Illinois (***DPSC*** pp. 9-1 3) [see p. 24]

Engineering Research Center – University of Minnesota (***DPSC*** pp. 80–85) "In the Center for Inter-facial Engineering, an NSF Engineering Research Center, we seek to be as innovative in our educational program as we are in our research activities. In meeting this challenge, we began by asking what we might be able to do that traditional academic departments could not do. We searched for ways to employ the technologies we were exploring in our research programs to enhance educational opportunities for our students, as well as researchers in companies, thereby integrating our research and educational issues."

Biotechnology Training Program – University of Wisconsin-Madison (***DPSC*** pp. 134-138) [see p. 24] "One goal of the BTP is to build on the existing disciplinary expertise of UW-

Madison graduate programs. As a consequence, BTP trainees will be positioned to become leaders in their field after graduation."

Multidisciplinary Education: Problem or Solution?

Graduate education, as some have noted, must become multidisciplinary. Certainly that is the way science is done, which is rather different from the way it is usually organized, taught, and learned. But we cannot forget that advances in what have become new disciplines have been derived from expertise in an existing discipline. Indeed the concept of multidiscipline implies the existence of single disciplines. Graduate students develop their expertise in well-defined areas, often called disciplines. The important component is that students learn to think beyond their disciplinary boundaries in order to frame and answer questions that are important, That is the nature of exploration and of risk-taking. Robert Lichter

The combination of these kinds of disciplines and human interests are driving the direction in which we are making our investments. . . . The capability that we need at the Oak Ridge National Laboratory, in order to support the users from the universities and industry, requires that we have people at the scientific and engineering levels who can work across these disciplines. So, fundamentally, from the point of view of the mission of the department, we need a work force that is prepared to operate in this very integrated science and engineering environment. Martha Krebs

If you think about it, a lot of interesting things happen at interfaces. For biologists, that may be the cell wall. For glaciologists, it may be the ice/air interface. For sociologists, it may be the interface between different kinds of people. A very ripe field for study, for people interested in the world, has always been to look at interfaces. And I think as we increasingly look at the interfaces between the disciplines, the interfaces between academia, industry, government, we're finding more and more things of interest [with which to become involved]. That means that students have to be trained in a different way-trained to cross those boundaries. Jules LaPidas

Two views on the proliferation of interdisciplinary and multidisciplinary programs were set forth by Forum writers. On the one hand, these programs were touted as the ideal response to the changing nature of the economy, labor market, and research needs of industry and student demands for increasing breadth in graduate education. These programs were credited with providing cutting edge exposure to the science and technology that "exist at the interface between disciplines," keeping research current and connected to industry, and providing students with professional skills necessary for success in a wide array of careers.

Others felt that introduction of multidisciplinary programs would burden an already overworked faculty and serve to increase the time to degree for graduate students. The current organizational structure of departments, lack of faculty professional development to teach multidisciplinary

programs, and the faculty tenure process were seen as major, but not insurmountable, barriers to implementing such cross-disciplinary programs.

Many recognized the need for graduate education to be responsive to the pressures for change and improvement. Multidisciplinary and interdisciplinary programs and research were endorsed by some writers as appropriate endeavors:

> The forces of change in graduate education have led to more interdisciplinary graduate programs. It is no longer sufficient for an individual to have depth in one subject area. He/she must exhibit breadth of knowledge as well in order to be successful in the nation's ever-changing workplace.

> I find it difficult to believe that significant improvements in the "education" component of graduate studies are not possible. These improvements could/should cover pedagogy used by graduate faculty in lecture courses, some experience with and learning about effective educational practices for the pregraduate school level for all doctoral candidates, and more emphasis on broadened disciplinary perspectives (even interdisciplinary experiences) and experiences in communicating specialized information to nonspecialists.

Richard L. Lintvedt and Gordon Melson commented on how multidisciplinary programs and research are important change agents for promoting positive growth in graduate education. Richard Lintvedt also stressed that removal of the barriers to interdisciplinary work is a necessary first step.

> I also was impressed by Geiger's statement about multidisciplinary education-it will go where *research* drives it. I am convinced that multidisciplinary education can be encouraged only by removing barriers to interdisciplinary research. Disciplines emerge from the knowledge base of interdisciplinary research. It happens continuously. Artificial barriers are often a major impediment to advancement. (Lintvedt)

> Interdisciplinary programs reflecting boundary "blurring" will become more important, especially in the biomedical sciences. We should (and are) responding to these changes by designing new programs that encourage interdisciplinary interactions for students and faculty. Examples are new doctoral programs in molecular medicine: Ph.D., M.B.A. programs, etc. **(Melson)**

Multidisciplinary and interdisciplinary experiences hold promise for providing graduate students with professional skills and interdisciplinary experiences needed for successful careers. Paul D. Nelson and Tiffany Barnes promoted the development of such programs and research:

> Most graduates employed outside the university (and perhaps increasingly within the academy as well) will be working in collaborative, interdisciplinary contexts on problems that are multidisciplinary in nature. With the long traditions of independent research within the discipline for the doctorate, how can we prepare tomorrow's doctorates to explore the interface between disciplines, to learn interdisciplinary collaborative skills and thinking habits? (Nelson)

> Since needs are arising on the boundaries between fields, I see more latitude given to students with creative ideas on these boundaries. We need the structure of graduate education to support this latitude. . . . Interactive teaching practices can start the process of interdisciplinary studies and ideas. Support for faculty time on teaching and integrating active learning and research in classes can help

in many ways. This can integrate student diversities and interests, let students know what research areas are being worked on. (Barnes)

Some writers cautioned the graduate education community that interdisciplinary programs and research are not a panacea for what ails graduate education. They wrote of the need to consider implementation problems such as budget constraints, structural issues, departmental organization, and the tenure process as constraints to institutionalizing these programs and research areas.

Interdisciplinary research (as opposed to intradisciplinary, which does occur) does not seem structurally feasible. I am curious about ideas folks might have for how this might be possible.

I have concerns about how to develop administrative structures to promote interdisciplinary graduate education in a time of restrained budgets: funding for initiating new projects is often available, but maintenance requires getting on general funds budgets. The superimposition of a cross-disciplinary administrative structure on the disciplinary base only adds to the costs of graduate education. How can we develop partnerships with the industrial sector that can assist us in developing programs with insured continued funding? Has this happened in specific settings?

There is a tension between the source of strength of graduate education-that it is centered in the departments and totally driven by the narrowly focused research of professors-and the need to provide a broader and interdisciplinary outlook to knowledge acquisition and creation. The speakers enunciated this issue in various ways, but failed to analyze the source of the problem and provide alternative paths to resolution of this tension. Funding agencies could help improve the interdisciplinary environments by providing alternative peer review of interdisciplinary research task 'forces. Only then will graduate students be exposed to a broad tool box of research techniques. (Manuel Gomez)

Barriers between disciplines must be reduced. The tenure process must recognize interdisciplinary work. (Pamela Kurstedt)

Donald Lewis wondered whether an interdisciplinary education is appropriate or even feasible for Ph.D. candidates and whether it is a path better left to postdoctoral fellows to pursue:

I see two problems. [One is] how to develop researchers in multidisciplinary research. As was noted, you must first learn a discipline, which takes time, and disciplinary departments tend to put up barriers to going too far afield. There is also the problem of learning vocabulary of a new field and something of its culture. This is too much to do on the way to a Ph.D., which is already too long for the financial return. Thus it would appear that this interdisciplinary education development must occur at the postdoctoral level. The universities that solve this problem will be the leaders of the future for the problems needing solutions that demand approaches of several disciplines. Another problem is that multidisciplinary research usually requires teams and [the difficulty of] assessing contributions becomes great.

A few Forum participants also challenged the assumption that faculty are ready to instruct interdisciplinary programs and conduct such cutting edge research. These writers called instead for providing faculty with more professional development and experience in these areas.

Much more attention needs to be paid to preparing faculty who teach in both undergraduate and graduate programs (e.g., interdisciplinary emphasis and use of technology). (Anne S. Pruitt)

***DPSC* citations**

Dual Degree Programs in Veterinary Pathobiology – University of Illinois (***DPSC*** pp. 9-13) [see p. 24]

Interinstitutional Multidisciplinary Ph.D. Programs – University of Puerto Rico (***DPSC*** pp. 35-37) "Of the ten Ph.D. programs in Science and Engineering at the University of Puerto Rico, the most successful are the ones in Biology, Chemical Physics, and Chemistry. . . . The distinguishing characteristic of these programs is their multicampus, multidisciplinary nature that optimizes the use of the resources available in Puerto Rico and provides the environment for interdisciplinary research problems."

Bio-Med Interdisciplinary Programs – Emory University (***DPSC*** pp. 129-133) "Until recently, as with most universities, bioscience research trainees at Emory worked toward candidacy for their degrees in a specific scientific discipline. . . . Almost without exception, the major advances in science have arisen at the interface between historic fields. In the early 1980s, Emory faculty members and graduate students from science departments began to establish formal group meetings and seminars series that focused on their common scientific interests. The culmination of these interactions, along with the recognition that bioscience Ph.D. training must cross traditional disciplinary lines, was the establishment of the Graduate Division of Biological and Biomedical Sciences. The Division is composed of eight interdisciplinary training programs, each leading to the Ph.D. degree. . . . Training foci are based upon the realization that an interdisciplinary approach is essential not only for the solution of research problems, but also for successful competition in modem biological and medical research."

Biotechnology Training Program – University of Wisconsin-Madison (***DPSC*** pp. 134-139). [see p. 24] "The BTP steering committee designed several program components so that students would have common cross-disciplinary training. It was relatively easy to integrate each of the following components within existing university or departmental degree requirements.

A set of courses was developed to expose BTP students to the cross-disciplinary approaches to emerging questions. . . . To provide students a cross-disciplinary perspective into their research topic, BTP trainees are required to appoint a minor research professor to their thesis committee from another area. . . . The required BTP student seminar series shows trainees how their peers or independent scientists from on and off campus bring cross-disciplinary concepts to bear on biomedical research questions."

Change Drivers: Internal and External Forces for Change

Forum participants wrote of the variety of pressures faced by graduate education today. Changes in the economy, society, public policy, and technology were all cited as "external" pressures on graduate education. Many also wrote about the "internal" pressures imposed by students, faculty, and administration to foster change in traditional programs. These driving forces were seen in a positive light by some, who expressed the belief that they will compel much needed improvements and revitalize graduate education. By contrast, others expressed concern that the pressures for change could provoke some unnecessary change and eventually work to undermine the quality of graduate education. The major change forces discussed at the Forum are presented in the following sections.

Industry Needs

We are looking at globalization in a way that we have not looked at it before, in terms of demographics and in terms of the economy. And we also are looking at changing industrial research needs. And all of these things form a context that is fascinating to be involved with as we talk about graduate education. Jules LaPidas

The message from industry is very similar to what the other speakers have already said. From our perspective the system is not broken. We're clearly buying what you're selling. . . . So clearly the graduate system within the United States in particular is producing both the breadth and the depth of scientific knowledge that we need, and the capabilities are there. My message is there are some minor areas for improvement and change. It is more evolutionary rather than revolutionary. [But there is] change that we would like to put forward for you to consider. Grover Owens

The challenge is that graduate education must now be customer driven. And the customers are not only the students who are in our programs but the employers, for whom they will find themselves [working]. We want them to keep their jobs because those employers will hire more of our graduate students. [We need a] rapid response, [that is] relevant, and applicable. Bernice Bass de Martinez

Some felt that graduate education must be more responsive to these needs of industry. It must, therefore, produce graduates with greater depth in professional skills, research experience, and ability to deal with complex, interdisciplinary issues, because the bulk of careers for graduates, now and in the future, will be in industry. Some even wrote that, unless students develop adequate professional skills and keep up with industry research and development advances, they will be unemployable. In short, a number of writers stated that graduate education needs to keep current with industry and reflect the state of an economy that is becoming increasingly high-tech and globally competitive.

Matthew H. Bruce elaborated on the perspective of industry and outlined the extent of industry needs:

I agreed with most of the presentations, but how the forces of change have affected graduate education assured me (at Proctor & Gamble) that the need is for scientists to have greater depth and to be able to deal with staggering complexity in very compressed time frames. Students, or new hires, who cannot handle these factors will experience limited success. In industry we have to deal with the convergence of several factors-the consumer, the government (regulatory agencies), and global competition. Scientists joining Proctor & Gamble must to be able to operate in one or more of these areas. Additionally, communication needs greater emphasis, especially for those with engineering backgrounds. The need includes writing as well as verbal presentations. Scientists should be encouraged to be at least familiar with related disciplines, e.g., chemistry/engineering, science/business or economics, and medicine/biology.

Similarly, Janet Boese outlined a potential response from academia:

Our industry leaders are concerned with the broader communication skills that newly minted Ph.D.s possess or do not possess. We at the American Chemical Society are looking to define our role in the training of **TAs,** the mentoring of minority students, the development of a broad yet sufficiently deep curriculum, and industrial experiences to allow graduates to cope with and contribute to a global environment.

Stanley Dunn and R. Timothy Mulcaby used the language of business and industry to describe the need to revise the current emphasis of graduate education to meet both industry and student needs:

Many of our students have become virtually unemployable in their chosen areas of study, as their areas are no longer on the forefront of science. It is difficult or challenging at best, to have our program accurately reflect both the state of the science and the state of the economy (1) at the same time and (2) with the same rapidity with which the economy changes. While it is true that industry "buys our products," we have to be able to produce a product that industry wants. This means, for me, to be able to quickly "retool the factory." Academia buys fewer and fewer of our products and we have to face this reality and move forward responsibly. Retooling means, in a practical sense, retraining the faculty in principles, not specific details. (Dunn)

Interestingly, industrial partners and government agencies all identify features of good graduate education that are similar to those identified by students. Both sets of "customers" are desirous of a similar product. (Mulcahy)

***DPSC* citations**

Dayton Area Graduate Studies Institute – Wright State University (*DPSC* pp. 69-73)
"The Dayton Area Graduate Studies Institute (DAGSI) is a collaboration among the graduate engineering programs of five universities located in and nearby Dayton, Ohio. . . . The DAGSI mission is to increase and improve the quality and quantity of graduate engineering education and research opportunities and, in the process, help create an environment conducive to substantial economic development in Ohio. . . . The Dayton, Ohio, metropolitan region has a long history of technological innovation dating from the Wright Brothers. . . . With strong corporate

and legislative leadership, the Dayton region was initiating [in 1992] a coherent program for economic development based upon technological strengths and a solid jobs base in the aerospace and automotive sectors. . . . Building upon the original community request for collaboration among the regional universities, the DAGSI partners enlisted the local corporate, military, and legislative leadership to support the DAGSI initiative as a regional priority."

Doctor of Chemistry – University of Texas at Dallas (*DPSC* pp. 74-79) [see p. 18]
"All 3 1 DChem graduates have found career R&D positions in industry, at the same salaries as Ph.D. hires; . . . DChem Industrial Practicum students and graduates have been hired at nationally recognized companies such as BASF, Coming, Dow, DuPont, Los **Alamos** National Laboratory, Merck, Rohm **& Haas,** Shell, Texas Instruments, and United Technologies."

Hazardous Waste Management Program – Idaho State University (*DPSC* pp. 94-102) [see p. 22] "Several major employers in eastern Idaho not associated with the **INEEL** also wanted the degree available for their employees. . . . To ensure that industrial, national laboratory, and state agency needs are being met, an Industrial and Professional Advisory Council was created. At least twice a year, this Council reviews the curriculum and provides information on the success of the graduates hired by these employers, the need for special courses, and opportunities for thesis research and internships."

Industrial Interdisciplinary Program – Virginia Polytechnic Institute **&** State University (*DPSC* pp. 103-106) [see p. 22]

Professional Master's Degree Program in Geosystems – Massachusetts Institute of Technology (*DPSC* pp. 119-124) [see p. 22]

Programs for Industrial Mathematics – University of Minnesota (*DPSC* p. 125) [see p. 23]

Changing Demographics

Very often there is a great deal of tension, as you know, in terms of the language differences and cultural differences. And graduate education, I think, has to help people bridge those gaps. Jules LaPidas

We need a work force that is comfortable with diversity because of the technology fusion that I have mentioned, both within the Department of Energy and also more broadly. This is a diversity that is first intellectual but also cultural because of the globalization of the marketplace; [the workforce] also is going to have to be comfortable, [due to] its very globalness with diversity in race and gender. Martha Krebs

Dramatic changes in the make-up of our society also are pressuring graduate education to change. Many attending the Forum wrote of change as an important responsibility of graduate institutions. However, both speakers and writers had more questions than answers. Many wanted to know how to effectively recruit, retain, and educate an increasingly diverse student body. They

also wanted to know how to prepare all graduate students to work in a more culturally diverse world, both within academia and in the private sector.

> I think there is a need for change not necessarily in the form of the quality of graduate education but in its "inclusionary" process. As the nation continues to evolve racially/ethnically, institutions of higher learning and industry will need to adapt to these changes to better meet the needs of society and maintain its quality. (Luis A. Melara)

> The panel skirted around diversity in graduate education. In particular, I refer to the recruitment and retention of underrepresented minorities in graduate education programs. Professors and administrators need to be made aware of concerns facing underrepresented minorities.

Many testified that the cultural and demographic character of the potential pool of graduate students is much more diverse than in years past. Graduate students are now more mature, come to graduate school with more employment experience, and include more women and minorities. Writers asked several questions about how academia can be more responsive to differences in gender, ethnic, and cultural backgrounds and at the same time meet the needs of mature, part-time career-oriented students. Forum participants also commented on the declining number of "domestic" graduate students:

> The influx of foreign students into U.S. graduate schools has been so great as to change the academic culture of some departments. . . . The graduate schools still lag behind in their progress of incorporating minority students into the graduate schools/departments.

> The graduate student population is becoming more diverse not only with women and minority students but also with international students. The international students, whose native language is not English and whose culture may be at odds with American culture, increase the challenge, particularly for team building. (Nina Roscher)

Jules LaPidas wrote of the need for graduate institutions to address the diversity issue broadly:

Universities have approached this issue [diversity], for the most part, by creating special programs for certain groups. We will have to move . . . to the development of university polices and practices that foster diversity. This has to be a universitywide policy matter. Scholarship and learning in an atmosphere of inquiry are at the core of graduate education, If that gets lost, the development of peripheral programs will not substitute for it.

DPSC **citations**

Graduate Education Enhancement Program for Underrepresented Minority Students in the Computational Sciences – Rice University (*DPSC* pp. 16-23) [see p. 24]

Graduate Education for Minorities – Universities of Arizona and Notre Dame (*DPSC* p. 24)

"The GEM (Graduate Education for Minorities) Consortium is a consortium of industries, colleges, and universities who are committed to increasing diversity in graduate education."

Graduate Experience Project – University of Michigan (***DPSC*** pp. 25-29) [see p. **24**]

Interinstitutional Multidisciplinary Ph.D. Programs – University of Puerto Rico (***DPSC*** pp. 35-37) [see p. **31**] "Data from the National Research Council show that 20% of all Hispanics who receive their Ph.D.s in Science and Engineering obtained a B.S. from the University of Puerto Rico (UPR). Of the ten Ph.D. programs in Science and Engineering at the UPR, the most successful are the ones in Biology, Chemical Physics, and Chemistry. . . . In these areas, 35% of the Ph.D. recipients are women. The distinguishing characteristic of these programs is their multicampus, multidisciplinary nature that optimizes the use of the resources available in Puerto Rico and provides the environment for interdisciplinary research problems."

McNair Program – Howard University (***DPSC*** pp. 48-52) "The Ronald E. McNair Program at Howard University was established in the fall of 1995. . . . Howard University is committed to placing its McNair Scholars into a year round academic and research program, as well as an intensive summer research program, all under the tutelage of faculty mentors. . . . An important aspect of the Howard McNair Program is intensive mentoring on the graduate school application processes for admissions and financial aid. . . . To date, all Howard University McNair Scholars have either completed, or are in the process of completing, their baccalaureate degrees. . . . To date, approximately 60% of Howard McNair graduates are currently enrolled in graduate school-a rate significantly higher than the graduate school matriculation rate for non-McNair Howard students, and significantly higher than the approximately 30% graduate school application rate reported for African American undergraduates."

Technology

And finally the last point, which I mention just generally because we're all dealing with it every day, and that is the incredibly dramatic effects of technology-by which I mean, the computer and all the things we mean by that general term— on learning, scholarship, research, and careers. It's changing the way we do things. It's changing the way we think about things in terms of our access to information, in terms of the scope of possible dissertation topics, in terms of the pace and nature of research. It's very easy now for people to work with colleagues in those seven departments in the world where the only good stuff is going on. And I think that we are going to be very concerned with this particular issue as we move into this next millennium. Jules LaPidas

Of those who wrote about technology and its potential impact on graduate education, most agreed that technology was expanding the boundaries of research within and across disciplines, providing opportunities for increased communication and collaboration, and setting the pace of change and growth.

All of higher education is being particularly impacted by the fact that current change in external (and to some extent internal) forces is both more rapid and more complex than we have seen before (as noted by Joe Bordogna). This is most obvious from the standpoint of technology (which creates both demands and opportunities). (Carol B. Lynch)

The world is rapidly changing demographically, technologically and economically, and that impacts graduate education. (Abigail Caplovitz)

I am keenly aware, for example, of the increasing synthesis between academia and industry and the need to be versed in the language of both. Also, as several speakers pointed out, the exponential growth of technology, in the form of computers and the Internet, virtually necessitates specific training in "informatics" (as we call it in the medical profession) at least. (Tony L. Goldberg)

Lisa Grable and Robert Kelly noted the implications of interinstitutional communication opportunities and globalization of research and scholarship afforded to graduate education via the Internet. Rowena Peacock speculated how these innovations and opportunities could impact graduate education in the near future.

The research focus, instruments, and the results are being shared with colleagues and potential research participants by means of the web, allowing for long distance interaction in very short time frames. (Gable)

Graduate education now must prepare for global linkages via the Internet with increasingly competitive and selective teams of individuals in emerging disciplines (e.g., new advances in physics, neuroscience, geomics). The concept of a "university " as a singular site is passe. (Kelly)

However, it is my view that graduate education change is occurring and will continue to occur rapidly as a result of the need to contain costs and as a result of the explosion in information technology. I believe that "learning" will become lifelong and will be supplied on demand, with professors developing and creating courses not as a part of a university faculty, but as "free lancers" who sell both their services and their expertise on an individual basis. A graduate education degree may be a combination of courses developed at several different "universities," which come from a variety of sources. (Rowena Peacock)

Not all writers, however, felt the influence of technology was positive. Some felt that technology was pushing the pace of change too quickly, might have an adverse affect on academic creativity, and work to shrink, rather than expand, communities. For example, Edwin Hahn, M. Apple, and Martha McCollum presented concerns about the rapid rise of the use of technology in education and the ability of departments to keep up with the pressures of information overload.

High tech links are a two-edged sword. Although fostering communication, they will counter the growth of innovation and diversity by making a follow-the-leader structure and hampering change. **(Hahn)**

New fields are emerging at an incredible pace, but department structures are still fighting the last war. (Apple)

> Technology has obviously embraced graduate education, but not everyone has embraced technology. (McCollum)

A few writers mentioned the challenges associated with technological advances, noting in particular the increased need for faculty professional development and student training in the use of technology. For example, Ken Pepion wrote, "Technology in teaching and research has heightened the need for technical training and the need to be technologically literate."

Finally, a few participants wrote of the need to address equal access issues, ensuring that the technological advances are available to all, at both large and small institutions:

> The Internet should not be used to create a few centers of excellence for each discipline. Instead it should allow individuals and small departments to participate in more advanced research at other locations.

> An increasing "fusion across technologies" requires an increasing investment in capital-intensive research and graduate education areas. (Michael Smyer)

DPSC **citations**

Master's in Science and Technology Commercialization – University of Texas at Austin (*DPSC* pp. 38-42) [see p. 18]

Dayton Area Graduate Studies Institute – Wright State University (*DPSC* pp. 69-73) [see p. 33]

A Ph.D. in Technology Management by Consortium - Indiana State University (*DPSC* pp. 112-I 17) [see p. 22]

Publishing Scholarly Documents Electronically – Virginia Polytechnic Institute and State University (*DPSC* pp. 195-202) "The objectives of the Electronic Thesis and Dissertation (ETD) initiative are to give graduate students access to multimedia tools to improve the quality of theses and dissertation; to have graduate students learn about electronic publishing and digital libraries, applying that knowledge as they engage in their research and build and submit their own ETD; . . . for graduate education to improve through more effective sharing of information in ETDs; and for technology and knowledge sharing to speed up, as graduate research results become more readily and completely available."

National Organizations and Funding Agencies

National organizations, such as professional societies, funding agencies, and other external social and economic forces, were cited as important change drivers. Some credited external pressures with fostering experimentation and innovation, while others wrote that the organizations place

uninformed demands on graduate institutions, with possible negative consequences. Much of the pressure for change is linked to various funding sources, many of which are placing new demands on graduate education and influencing the very nature of research and education.

Some participants emphasized that external pressure for graduate education reform can serve to instigate program improvement and reflection and work for positive experimentation:

> From my perspective the forces of change have led to programmatic "experimentation" in the areas of attracting and supporting diverse populations by looking at the educational needs of students, at both the graduate and undergraduate level. The specific drivers of these experiments have come from "outside" demands for change-society, industry, NSF, and students. (Kathy Luker)

> In the last decade, particularly since the early 1990s, it appears that external forces (outside the academy) have begun to exert greater pressure on graduate education to be more responsive. Historically, graduate education growth in science and engineering was an outcome of WWII and post-WWII needs that were external to the academy. Today, the economy is the driver. In this scenario, graduate education has been forced to look at itself and answer three questions:
>
> 1. What is the role and function of research in graduate education?
> 2. How do institutions balance their research and teaching?
> 3. How do we (the academy) communicate the outcomes of these decisions?

A few welcomed the role of government as funding resource, facilitator, and change agent, noting that the government is uniquely situated to initiate change and provide incentives unavailable from individual institutions:

> Funding mechanisms (e.g., NIH Interdisciplinary grants, NSF IGERT) can provide incentives for cross-discipline and cross-profession collaboration. Currently, however, they provide little in the way of incentives or demands for other aspects that have been highlighted in the meeting (e.g., training in communication skills; internships in industry or other settings). However, if the funding sources (federal or private) change the incentives, smart people like faculty will change their behavior. (Michael Smyer)

> Government should be a facilitator of the confluence between industry and academe. This should translate to industry and graduate departments coming together and, more specifically, to graduate students taking some of industry's problems as research problems.

At the same time a few encouraged the graduate education enterprise to proceed cautiously with reform efforts and to consider external demands carefully:

> The panelists touched on what, to me, is a key issue in "reforming" graduate education: How much of the drive for change is fueled by informed consideration and how much by misconceptions and ignorance? Much of the clamor for changes comes from entities that are conspicuously disconnected from the graduate (and even the university) enterprise-legislators, journalists, other politicians, and even university trustees. The challenge is to separate such attacks from a drive for really needed change, and then to address those issues. (William Clark)

Forum writers confirmed that years of federal funding have both enhanced and constrained the research environment. The funding from both federal and private sector sources has greatly

influenced the research emphasis of many faculty and students and affected the scope and application of the research, as Krisbnan Subramanian wrote:

> The focus of graduate education has visibly changed due to the change in the roles of the different organizations involved in the graduate learning process. There is a **slow shift** in funding sources away from the government sources to industry [sources), and the graduate university programs are moving from pure science to applied science.

However, the power of funding can sometimes produce unintended outcomes. According to Robert Rich, government funding resources have served to channel students into research positions, but also have distracted graduate institutions from addressing students' educational needs:

> Claims of the preeminence of the student's needs notwithstanding, the primary driving force in today's research university is the abundance of federal research funding that can he used to fund graduate students. While it is a good thing that government has chosen to invest in research, it is au unfortunate side effect that Ph.D. production has been divorced from the educational imperatives of the student.

Some wrote that the changing nature of the funding streams for graduate education is redirecting institutional priorities and changing the face of graduate level research:

> American industry is providing more short-term, underfunded, project-directed **grant and** contract money to professors, **and** in **many** universities these funds are supplanting the full overhead-bearing federal grants. (Ned D. Heindel)

> Resource constraints **and** declining funding for graduate education are forcing smaller institutions (who are left out of the research institution government funding loop) to downsize programs or look to fulfill industry needs to make budgets. (Narayau Bhat)

> A major force not mentioned was pressure from the legislature to make undergraduate education a priority. Thus graduate education receives fewer resources and attention and is almost a dirty word. (Louis Terracio)

DPSC **citations**

Career Information Services – Sloan Foundation (*DPSC* pp. 7-8) [see p. **18]**

Engineering Education Scholars Program – University of Wisconsin-Madison (*DPSC* pp. 14-15) "To remain competitive and yet foster partnerships, U.S. higher education requires better integration of both teaching scholarship and research scholarship. Likewise, the U.S. economy requires that some of our best and brightest young people choose to enter the engineering profession. In addition, both pedagogical techniques and content knowledge are necessary to prepare effective teachers for engineering classrooms. To these ends, the University of Wisconsin-Madison proposed and received National Science Foundation support to implement a cultural change approach to engineering education. . . . The goal of the program is to 'provide a

professional development program that will help those who seek an academic teaching position become more competitive."

Graduate Education Enhancement Program for Underrepresented Minority Students in the Computational Sciences – Rice University (*DPSC* pp. 16-23) [see p. 24]

Graduate Experience Project – University of Michigan (*DPSC* pp. 25-29) [see p. 24]

Engineering Research Center – University of Minnesota (*DPSC* pp. 82-85) [see p. 27]

GOALI – Louisiana State University (*DPSC* pp. 86-90) [see p. 22]

Biotechnology Training Program – University of Wisconsin-Madison (*DPSC* pp. 134-138) [see p. 24]

The National Preparing Future Faculty Program – Central Office (*DPSC* pp. 169-17 1) "The Association of American Colleges and Universities, the Council of Graduate Schools, and the Pew Charitable Trusts are pleased to continue their efforts to improve graduate and undergraduate education through the Preparing Future Faculty program."

Student as Consumer

I think that there's a dynamic arising from the very power that students have. Their favorable bargaining position means that doctoral programs with innovations that are more attractive to the top students will flourish. And I think this has happened-I give the example in my paper of the fact that, for some time now, universities have been offering teacher training for graduate students who were hoping for academic careers. And of late, this has become increasingly popular as students see an advantage in having such training in securing academic positions. I think the same thing will occur in terms of the broadening of doctoral programs to provide skills that are more appreciated outside ofacademia. Roger Geiger

Pedro Reyes wrote, "The most powerful factor for change in universities is the student." Forum panelists and participants generally agreed that students are becoming more educated consumers of graduate education. Indeed, some went so far as to describe the current situation in graduate education as a "buyer's market." Many observed that students are more proactive in demanding specific services and determining the parameters of their education, and that these demands are being heard and beginning to reshape graduate education. Some Forum participants wrote about the extent of this student pressure for change, describing student demands for such programs and services as career preparation, multidisciplinary programs and industry internships and research experience.

> [There is a] shift in power: students in the buyer's market, exerting a market force influence over what changes can occur. Student [demands are] becoming a core concern. (Abigail Caplovitz)

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> I have seen the increase in pressure from the graduate students themselves to incorporate a broader range of participation in their education. . . . The notion of student-centered, student-d riven graduate education is more in line with preparation for later tasks than the faculty-driven progr ums we have discussed. (Marilla D. Svinicki)
>
> Currently, prospective graduate students are more "sophisticated" than in past decade ; in terms of their experience (many have research experience as undergraduates), expectations (th y are looking for specific types of opportunities, experiences) and [level of] knowledge about caree s and how the system functions. This has created a competitive atmosphere among universities to at ract the best students. Student pressure, then, provides a major driving force for change; many inst tutions are attempting to adapt to this "selective pressure." (R. Timothy Mulcahy)
>
> At New York University I have served as an ambassador/orienter for graduate student recruitment. Every student I talk to speaks like an educated consumer/smart shopper. They know v hat interests them. They know how the school is ranked/viewed. They have a sense of the job marl et, and specific concerns/questions about how the school would serve their interests. Perhaps graduat students have always been this way, but I believe that the era of downsizing (workplace transience), identity politics/celebration, global competition, and other forces are producing students well versed in their enlightened self-interest. These people will be the fundamental driver of change withi the universities. (Abigail Caplovitz)

One graduate student attending the Forum illustrated the impact of student involve nent by describing a scenario in which students initiated an institutional change process:

> I have a different perspective from the speakers, since I am *still* a graduate student-z nd one in the humanities to boot (though I work in a program that includes scientists and social scie ntists). The model for change that I have observed in my six years in grad school has been someth ing like this:
>
> - Early 1990s: *Crisis* (real or perceived) in graduate education as Ph.D. student become aware of the shrinking job market;
> - ***Indifference*** from most faculty and administrators (and certainly from the inst ution as entity) to this crisis;
> - *Action* by graduate students, either on their own or with the cooperation of syn ipathetic faculty, to piece together programs that address these issues;
> - *Skepticism* from institutional forces about the efficacy of these programs;
> - *Praise* for these programs from outside observers and from students themselve s;
> - Support from alumni (including financial support);
> - *Reconsideration* by the institution of its role; and finally,
> - *Reconciliation* of the different groups in an attempt to strengthen and institutio aalize the grassroots programs.
>
> This is a simplified view, and I do *not* mean to say that every faculty member and ever administrator has been so hostile or apathetic. However, change at the institutional level has been sl w—and *risky*, as many of this morning's speakers noted. In my experience, the strongest impetus for change has come from students-we have nothing to lose and everything to gain.

Another writer recommended recognition of student involvement as an important c hange agent that could be effectively leveraged for addressing pressing issues at graduate institu tions:

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In his paper and during the discussion, LaPidas emphasized the importance of students and their interests as forces of change. Perhaps the issue of student interest as driver—warrants more systematic attention than it has received. Just possibly, greater concern with that interest might help address a topic that everyone mentioned: the limited demographic diversity of graduate education and the workforce in science and technology.

DPSC citations

Dual Degree Programs in Veterinary Pathobiology – University of Illinois (*DPSC* pp. 9-13) [see p. 24]

Graduate Education Enhancement Program for Underrepresented Minority Students in the Computational Sciences – Rice University (*DPSC* pp. 16-23) [see p. 24] "Often the most talented minority students have never had to develop survival skills. They have not learned how to ask for help or how to construct support groups. [Professor] Tapia guides them through this process, and also enlists the help of group members who have survived similar problems. This builds a feeling in the older students that they are 'giving back,' which is a very strong need for most minority students at a majority school."

Graduate Experience Project – University of Michigan (*DPSC* pp. 25-29) [see p. 24] "The programmatic interventions established by the Graduate Experience Project include the Peer Advising Program in which upper level women graduate students serve as peer advisors to incoming women graduate students."

McDougal Graduate Student Center – Yale University (*DPSC* pp. 43-47) "The McDougal Center is a center for graduate student life and professional development at Yale University. . . . The McDougal Center provides space and program funding for building intellectual, cultural, and social life, and for facilitating professional activities across the departments of the Graduate School of Arts and Sciences. . . . In 1995, the Graduate School formed a Planning Group of graduate students, alumni, and interested faculty to determine what programs the new Center should sponsor and what sort of space would be needed. The Planning Group conducted an intensive outreach program to ensure that all graduate students had an opportunity to participate in the planning process so that . . . the programs in the Center and the renovated space truly reflect the expressed desires of graduate students. . . . The Center works best when it involves students as peer programmers, event organizers, and peer advisers, as well as participants in the programs themselves."

Speaker Series – Cornell University (*DPSC* pp. 67-68) "The Cornell Mathematics Department began in 1994 to design a low-cost, high impact program whose goals would include giving graduate students some idea of what teaching at the college level entails. . . . Faculty are involved in this program as necessary, but the administration and coordination are controlled by graduate students who suggest, organize and carry out the talks and trips. The PFF program, originally

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funded by the Pew Trusts, is now a fully self-supporting departmental program financed through the Cornell Arts College Deans' Office."

Biotechnology Training Program – University of Wisconsin-Madison (*DPSC* pp. 134-138)
[see p. 24]

Conditions for Change: Context, Structure, and Culture

The universities, of course, all make rules about graduate education. They all have policies, but department policies are much more important, and the policies of individual laboratories, individual professors, are even more important. The big difficulty under the current situation is that centralized policies have very little leverage. And consequently, it seems that reform, if it's going to occur, is likely to come from the grass roots, which is precisely what this conference is all about. Instead of talking about what the government ought to be doing about graduate education, we can look at what is actually taking place at the departmental level or laboratory level and see whether innovations there are bringing about a change in the nature of doctoral education. Roger Geiger

Writers mentioned several essential conditions to consider for effective change. Writers reminded the graduate education community of the need to understand institutional and political contexts and the experiences of certain stakeholder groups, particularly graduate students, postdocs, and faculty. Many articulated their concerns about the decentralized nature of graduate education institutions. They also elaborated on the intricacy with which formal and informal structures within institutional organizations need to coexist and work together for successful innovations to become institutionalized. Forum writers also reminded us that how individual institutions support and respond to change also plays an important role in determining faculty attitude and motivation toward change.

Institutional Change and Context

Each institution provides its own context for change. Desired practices, obstacles to change and needed change may differ dramatically between your institution and those of the others in this audience. We are not trying to prescribe any particular strategies for change, but we want to offer our own stories as examples of how change in graduate education is possible. Jan Smith

Writers agreed that, to be viable and effective, those planning to initiate change or innovation need to take into account individual institutional and political contexts. Each institution needs to deal with its own unique set of circumstances to effect positive change, wrote several think piece writers. In so doing, strategies employed will be more likely to suit the formal and informal structures already in place, and best meet the needs of faculty and students. Michael Smyer and Diandrea Leslie-Pelecky wrote of the importance of context in their think piece essays:

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> The main theme I take away from this panel is the old adage, Think globally, act locally. Each institution must confront the challenge of change within its own context of history, mission, resources, and opportunities. One theme that was implicit, but that needs to be emphasized, is the importance of institutional change in order to facilitate the recruitment, education, and employment of the next generation of graduate students. . . . The success of and importance of specific strategies will depend upon the particular constraints and opportunities embodied in your institution's history, organizational culture (including fiscal arrangements) and stage of development. **(Smyer)**

> [There are] differences involved in change when change occurs through different units (i.e. individually motivated, departmentally motivated, administratively motivated, etc.). This is a critical distinction that needs to be made. (Leslie-Pelecky)

Stacey Lane Tice and others wrote that students and faculty are more likely to buy in to the program if the proposed change builds on localized circumstances and grassroots commitment:

> The greatest successes seem to come when impetus for change is alive at the institution within the department or group of faculty, and the program offering funding is a good fit to an already envisioned entity.

> I think that the notion of change can be very threatening and that the strategies employed should be appropriate to the national, institutional, and departmental context. For change to be lasting it must be embraced by the faculty and become a part of the academic culture. And all efforts of reform should be continually assessed-change for change's sake will probably not be as effective as we would like. **(Tice)**

Ric Weibl also reminded the graduate education community that there are many different paths to successful reform:

> The initiative for innovation comes from many different places. Does the structure/path of development to institutionalization vary depending on the point of origin?

***DPSC* citations**

Career Services for Doctoral Students in Science and Engineering – University of Pennsylvania (*DPSC* pp. 1-6) [see p. 18] "It may take some time for career services staff to earn credibility with the majority of faculty members, many of whom will be unfamiliar with the idea that those who work outside their field may have an understanding of its particular demands and requirements. . . . While services to graduate students were being expanded in the 1980s, there was a Faculty Advisory Committee. Inviting faculty members to speak at programs introduces them to career services for graduate students. . . . The Vice Provost for Graduate Education co-sponsors most major programs with Career Services and also speaks at the annual Academic Career Conference, where she often addresses entering students with a talk about what they and their departments can expect of each other."

McDougal Graduate Student Center – Yale University (*DPSC* pp. 43-47) [see p. 43]

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Biotechnology Training Program – University of Wisconsin-Madison (*DPSC* pp. 134-138) [see pp. 24 and 27] 'The organizational structure makes it important to match students with affiliated BTP faculty members. The BTP steering committee believes that cross-disciplinary student training is maximized if a critical mass of qualified trainees and faculty trainers are identified from programs across campus. When the goals and components of the BTP were outlined at a series of 'faculty town meetings,' a large pool of high quality faculty volunteered to serve as trainers. Today, there are over 100 affiliated BTP trainers from more than 40 denartments."

Institutional Structures

I am going to talk about institutional policy as one strategy for change. . . . Sometimes I describe our institution as a loose confederation of fiefdoms geographically proximate, and that that's probably all we have in common. But, nevertheless, we think that some policies are effecting change, and I'll give you a couple examples. The first one is the policy of supporting and nurturing interdisciplinary Ph.D. programs within the graduate school. Certainly our Molecular and Cellular Biology program is an example of that. Right now we have a number of interdisciplinary programs that are waiting to be housed in the graduate school, to be developed, to maybe then go on to become departments or to stay in the graduate school. And that is a very strong strategy for creating interdisciplinary graduate education programs. Jody Nyquist

> I think probably the traditional role of some graduate schools has been more to provvide management than leadership. One way to think about the role and resources of a graduate school is to see it as a source of intellectual capital, and what I mean by that is a place where ideas can be generated and tested before they take root in local schools or colleges or departments. And Jody's notion of having interdisciplinary programs initially be sponsored by or initiated by the graduate school and then eventually spun out when appropriate, if appropriate, to local departments, schools, , and colleges, makes a lot of sense to me. That is what we are doing at the University of New Hampshire with both doctoral and master's programs. Faculty perceive the graduate school, right now anyway, as a relatively safe environment for that kind of experiment for interdisciplinary programs, free from the political noise that always arises around interdisciplinary programs. And once the bugs are worked out over a period of a few years, then the question is posed: is it now time to put this out in one or more departments at the local level? (Bruce Mallory)

We are not done with our institutionalization effort, but we understand now that it takes a continuous attention to the ebbs and flows of political change on the campus to decide which strategy to apply when, in terms of bringing about the change desired. Jan Smith

Many writers used the words "decentralized" and "rigid" to describe the current graduate education enterprise. The system was described as being resistant to change and rigid in its adherence to tradition. In addition, the decentralization of decision-making and responsibility in graduate education programs was criticized for making comprehensive change difficult, increasing competition, and hindering innovation and improvement. A few writers also characterized management organization, departmental structure, and out-dated tenure and reward systems as major impediments to change.

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The following writers expressed their views on how difficult it is to bring about change in a graduate education system characterized as diffuse and resistant to change:

> Recognition of the need for change is impaled on the structures and inherent lethargy of the institution. Dispersed governance within the institutions makes decisions about graduate education difficult. (Robert A. Jones)

> Institutional structures and organization (college, departments, etc.) are not always conducive to change. This is compounded by reluctance from faculty to alter the system they have in place for educating graduate students. These two facts make necessary changes to accommodate interdisciplinary efforts etc., very difficult. Effective change may require dramatic (or at least creative) restructuring of university structure and organization to achieve synergy. (R. Timothy Mulcahy)

> LaPidas was especially good at framing the issues-things have not changed that much but the "system" does not lend itself to what the world *is*. Policymakers may be criticized for their attempts to make minor changes to the system-but it is a system that is both rigid and decentralized. This difference makes it hard to change. The problem is similar to herding cats.

> The internal management of our universitywide graduate operation has been increasingly decentralized. We have had great difficulty managing (almost) everything at the school level—from admissions to financial support to virtually all student services. . . . The running of our academic enterprise has become extremely difficult.

Some stated their belief that "real change" within institutions is to be found at the level of the classroom and lab, and that ultimately important change is that which positively affects students' learning. The decentralized structure of most graduate institutions was less of a problem for some. These people wrote of grassroots change working from the bottom up:

> It was mentioned that graduate education is decentralized down to the level of the individual laboratory or research supervisor. Those who are most innovative and entrepreneurial at this level will be the most influential initiating change and providing incentives, money, and other resources. Successful changes then will percolate to higher levels. (Joseph F. Thomas, Jr.)

> The point about decentralization (Martha Krebs) was a valid one. Truly the rules of the lab, department, or faculty will be of more importance to doctoral students than universitywide polices that never reach the local level. On the other hand, more faculty seem willing to realize that the job market is difficult and different from when they entered it, and that students need help looking beyond the traditional career paths. Hopefully, some faculty are seeing that the education needs of the students must be as important as their (the faculty's) own research needs.

Max C. Poole and Jules LaPidas wrote that there is still an important role for administrators and institutions to shape policy and practice:

> As an associate graduate dean, one of my realizations is that we really have little authority over the university's faculty, administration, etc. However, our greatest influence is through the use of "moral authority" in persuading and educating others to "do the right thing." (Poole)

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Given the highly decentralized structure for doctoral education, often centered on individual faculty members, it becomes incumbent on the university to bring its scholars together across disciplines, to develop a framework within which all of this takes place. An example is the question of inclusiveness. Universities have approached this issue, for the most part, by creating special programs for certain groups. We will have to move away from this to the development of university policies and practices that foster diversity. This has to be seen as a universitywide policy matter. Scholarship and learning in an atmosphere of inquiry are at the core of graduate education. If that gets lost, the development of peripheral programs will not substitute for it.
Jules LaPidas

A few debated the role of departmental structure and faculty tenure as possible impediments to institutional change and innovation:

> I agree with Dr. Roger Geiger that graduate education is decentralized. I think that the tenure system directly impacts graduate education and is a factor that has to be kept in mind when speaking of change. Younger faculty are often the ones with ideas and motivation to change education and be innovative. However, the demands placed on them by the tenure system often preclude them from acting out ideas. It is seldom possible to start a research program, obtain funding, and contribute to changing the existing structure of graduate education. (Leonie Boshoff-Mostert)

> [There is a] need for multidisciplinary programs, but current departmental structure is a constraint for both graduate students and junior faculty concerned about tenure. . . . Decentralization inhibits ability to initiate large-scale policy changes; most decisions are made at the department or individual lab level. (Leonie Boshoff-Mostert)

> An increasing fusion across disciplines requires an increasing flexibility in university recruitment, hiring, and tenure/promotion processes, [all of] which are still largely discipline-based. Doctoral education is decentralized. While central leadership on these issues is necessary, it is not sufficient. Faculty leadership at the departmental, program, and lab level is essential. (Michael Smyer)

***DPSC* citations**

Career Services for Doctoral Students in Science and Engineering - University of Pennsylvania *(DPSC* pp. 1-6) [see pp. 18 and 45]

McDougal Graduate Student Center – Yale University *(DPSC* pp. 43-47) [see p. 43]

Biomedical Interdisciplinary Programs – Emory University *(DPSC* pp. 129-133) [see p. 31]

Biotechnology Training Program – University of Wisconsin-Madison *(DPSC* pp. 134-138) [see pp. 24, 27, and 46]

Future Professoriate Project – Syracuse University *(DPSC* pp. 146-152) "As a research-oriented university offering approximately 190 graduate degrees, Syracuse University resembles other institutions in its use of graduate students as teaching assistants. Beginning in 1987, the

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Graduate School initiated its TA Program, which consists of a two-week orientation program for new **TAs** and a set of ongoing support activities aimed at improving the quality of instruction they provide to undergraduate students. Currently, working in partnership with the academic departments that appoint teaching assistants, the program offers a variety of services. . . . In 1991, with support from the Pew Charitable Trusts, the Fund for the Improvement of Postsecondary Education (FIPSE), and the Chancellor's Fund for Innovation, the TA Program launched a Future Professoriate Project. . . . Since the project's inception, 199 faculty teaching mentors have been appointed in 52 departments distributed through eleven of the University's thirteen colleges."

Faculty Culture

The most rudimentary understanding of organizational change tells us that when we turn to the task of change, we need to focus on two targets: our institutions and the attitudes of people in them. In my experience in graduate education and in life in general, these two are intimately intertwined and the fact of the matter is, no innovation will succeed unless you de al with both institutions and the attitudes of people in them. Debra Stewart

Sometimes it's not always clear what drives the push for restructuring graduate education, what are the underlying drivers. The fixes can often seem to be tinkering at the edges of a structure that is solidly grounded-that point has been made here. Sometimes it's hard to avoid the sense of a general feeling of discomfort without a crystalline concept of what the problem is. The issue is figuring out how to locally institutionalize those opportunities that matter. Directing the efforts toward students and engaging the students is certainly a plus, and absolutely necessary. But it's not clear that it's sufficient, since the change requires faculty to buy into the effort, and faculty really are the lynchpin in any mechanism for improving the circumstance. A number of programs described in the Forum book, Descriptions of Programs and Strategies for Change, ***acknowledge this and try to address the question, "What's in itforfaculty?" New components of graduate education are often perceived by established faculty as distracting and detracting from the fundamental role of graduate students, and I have been in some pretty intense discussions with faculty about that. That fundamental role, of course, is to be in the lab, finish the dissertation, and get a job. That will not change by administrative fiat and is unlikely to change by providing short-term incentives. It may be facilitated, and this point I have not seen addressed in any of the materials, by engaging the disciplinary societies. I think that is an area where there's some discussion [needed].*** Robert Lichter

We did it by thinking about the problem creatively and seeking solutions that did not require a lot of infrastructure, but kind of pushed the existing envelope of things that were in place on campus. We basically built on existing cultures. . . . We also built on an interest of faculty who sought out faculty trainers who believe [cross disciplinary] training would be good from a scientific perspective for their own little research labs and from an educational perspective for training the next generation of students. Timothy Donohue

Many at the Forum wrote about prevailing faculty attitudes and departmental cult ure as major impediments to improving graduate education and moving toward a system that is more

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responsive to student and industry needs. Writers described the problem as one of faculty and departmental resistance to change, characterizing senior faculty especially as rooted in tradition and reluctant to try new strategies. Others explained the problem as a lack of awareness or knowledge on the part of many faculty. They prescribed further dissemination of information, professional development, and ties with industry to build faculty understanding and promote improvement.

In general, writers agreed that most graduate institutions experience this resistance in one form or another. Several writers attributed the general resistance to change to the entrenched attitudes of faculty, stating that some faculty still focus on producing "clones" of themselves through an outdated apprenticeship system that requires students to conduct the faculty's research and prepares students for limited academic positions. Others were less severe, noting that departments and faculty may be reluctant to change because of traditional campus culture, basic inertia, or their lack of understanding of new concepts and strategies. As one person wrote, "One of the biggest obstacles . . . to institutional change is campus culture and the aversion most people have to change."

> Institution structures and organization (college, departments, etc.) are not always conducive to change. This is compounded by reluctance from faculty to alter the system they have in place for educating graduate students. (R. Timothy Mulcahy)

> Departments tend to be very conservative and resistant to change. But innovation must involve and begin with faculty. How can we foster the blurring of departmental boundaries? What is the role of central administration of the graduate school in this process? (Peter Syverson)

Some writers elaborated on the point that faculty reluctance to innovate and shift more attention to graduate student learning and professional development stems from their focus on research, emphasis on academic placements for students, and adherence to an academic culture that devalues industry careers.

> Major professors are too concerned with the bottom line-research-to carefully assess a student's strengths and weaknesses in order to give career advice. Often the major advisor at best can suggest a company or school that is doing "good work," without any recognition of the student's needs.

> The reaction of the faculty has been noteworthy in its inaction and nonconstructive discussion. The department still functions and makes decisions at the faculty meeting level in which discussions rarely lead to experimentation or risk-taking. "What's in it for me?' say the faculty. Our program is still driven by the desire of faculty to bring students to their labs as quickly as possible for the benefit of their individual research programs. Depressing? Yes! Yet, I don't see change generated from within the department or graduate school. How can/will outside forces bring constructive and ordered change?

Several people described the faculty problem as a lack of awareness on the part of faculty of changing educational needs. Pamela Kurstedt asked the following question: "How do we make faculty aware of expectations of stakeholders in change?" Other writers had similar concerns:

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On my campus, it appears that the students and the deans of the graduate school are aware of changing student and societal needs, but the faculty remain blissfully unaware. This is likely to remain true. (Patricia M. Sakolove)

More discussion is needed on the roles of the university and graduate education in serving society. It cannot be overstated that an overwhelming majority of graduate students will not find work in academia. At the same time the faculty are "blinkered" in that they are largely unaware and inexperienced with professions beyond the university. (Bo Hammer)

For the most part, senior faculty resist most change in the status quo; the disjunction between "old" and "new" is really disconcerting. Students get caught in the middle and then morale drops. One of the areas generating the most tension is the need for us to understand how to help students prepare for jobs in biotech/industry, so the comments by the last speaker from Proctor & Gamble were especially useful.

Among the leaders of science and engineering, faculty mostly, most issues of change in research universities and graduate education provoke a certain perplexity: "What is this all about? Things are fine at my institution, in my department." It worries me that this attitude means that the leading institutions are unlikely to lead change.

An outdated faculty reward structure, which offers few, if any, incentives for faculty to implement change and focus on education rather than research, was also identified as an impediment to improving the graduate education system.

In graduate education, what are the incentives for faculty to focus on education needs as distinct from the needs to advance their research program? (Barbara O'Kelly)

As the retirement gap between tenured faculty and struggling graduate students, postdocs, and junior faculty grows, I see the loosening of some of the personal connection of loyalty and trust (in both directions) that may have provided some of the strongest safeguards against cutting corners. I worry sometimes that the system is eating its moral capital because it's a resource that is so close to invisible. When success is measured by grant dollars, what happens to the integrity that supports wild new ideas that can not prove themselves without time to incubate, that acknowledges the new advances, that undergirds the work on which one's own professional reputation is based, and that is willing to take a stand against scientific fraud and misconduct?

For faculty to make significant change, they need to see feedback in the form of money, or tenure promotion, or support of their individual research programs. In reality, faculty need to be convinced that not implementing positive, academically sound change will mean that the best and the brightest students will be going to those institutions that are meeting their needs. (Marcia G. Welsh)

In order to change one of the barriers to "alternative placement " of Ph.D. students-faculty resistance-we need to change the reward system for faculty and institutions to include rewards for such activities. While federal funding is still extremely important, we need to look at ways to reward faculty and universities for generating private funding. (Thomas Callarman)

The professional society also might engage itself in strategies that would support risk-taking among its members. Those actions would stimulate a change in the culture of conformity. "Science is about

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open-minded exploration and discovery, but the practical aspects of its practice have to do with not wanting to go too far outside what convention dictates today." (Marilyn Schlitz)

Scott LaPierre agreed that faculty and departmental attitudes toward change are important, but contended that pervasive faculty resistance to change is a myth. He wrote about his own positive experiences with faculty:

> The changes, especially in terms of a shrinking academic job marketplace and a burgeoning industrial sector, have had a ***huge*** impact on attitudes towards graduate education. Professors who shut their doors at the mention of an industry representative setting foot on campus are mythology, from my short-term perspective. Faculty swing doors wide at the prospects of industry collaboration. It is about survival, but it is also about opportunity.

Many at the Forum were reluctant to blame faculty for their reluctance to pursue innovation and change. They wrote that it is unfair to expect faculty to assume new and more diverse roles as advisors, mentors, and career counselors without first providing the proper professional development, information, and support. These writers called for workshops, information on "best practices," professional development in new teaching methods, exposure to innovative graduate programs, and industry experiences to bring faculty on board and give them the information necessary to understand and implement new changes.

> The heart and soul of graduate education is the mentored learning experience. How are faculty prepared to assume this role? Do we have faculty development programs to help new (and older) faculty identify and develop effective pedagogies that work for their personalities, science, and teaching goals? (Paul Ilecki)

> There are many faculty who are open to doing things differently, but don't know how. We need to engage them, train them in being coaches rather than references. (Barbara O'Kelly)

> I think also that we must work with the faculty since they may either not be familiar with those options or be too comfortable with where they are and not be so willing to change and to look beyond their immediate worlds. . . . The openness to which I refer also should extend to multidisciplinary and multicampus experiences. It's been my personal experience, as faculty, that I have gained much from working with faculty from other disciplines and those skills and knowledge have certainly contributed to make me a more grounded professional. (Norma Davila)

***DPSC* citations**

Doctor of Chemistry – University of Texas at Dallas (*DPSC* pp. 74-79) [see p. 3] In the mid-1970s, when the University of Texas at Dallas sought approval from the Texas Higher Education Coordinating Board for a doctoral degree in chemistry, the Coordination Board staff were well aware of the difficulties chemistry Ph.D. graduates had faced in getting jobs in 1971-72, and they generally opposed the addition of new doctoral capacity. . . . By the time the program had been drafted, redrafted, and finally approved in 1982, the chemistry faculty had come to understand

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the DChem idea as a challenging and worthwhile opportunity to test a (hopefully better adapted) educational idea."

Bio-Med Interdisciplinary Programs – Emory University (*DPSC* pp. 129-133) [see p. 3 1]

Biotechnology Training Program – University of Wisconsin-Madison (*DPSC* pp. 134-1 38) [see pp. 24, 27, and 46]

Promising Practices and Strategies for Implementation

At North Carolina State we recognized very early on that to successfully introduce innovation in graduate education we needed to find ways to walk a fine line between a set of dual responsibilities. We needed to maintain stability, while simultaneously promoting change. We needed to preserve the valued traditions of graduate education, while simultaneou sly fostering important innovations that our stakeholders were telling us about and challenging us to do. [On the one hand] we needed to articulate and enforce policies and procedures, while on the other hand constantly struggle for ways to find flexible applications of those same policies and procedures. And finally, and most importantly, we needed to find ways to exercise power and authority, while simultaneously empowering students and faculty and all ofour stakeholders to engage in a meaningful way in decisions about the process. Debra Stewart

In this section, writers discuss graduate education in terms of what should be changed. This is a topic not taken lightly, as many noted that there are many qualities that have made graduate education in the United States great-and these should not be compromised. However, trends in the job market and the changing needs of business/industry and students have alerted stakeholders that some changes are necessary. These writers described various change initiatives in graduate education and offered solutions that can help stakeholders and institutions initiate and sustain these changes. Writers made suggestions about how to initiate and/or sustain change. Solutions included

- empowering students to make informed.decisions about their education and to be change agents;
- using funding as leverage for change;
- restructuring reward structures/create incentives for faculty to become involved;
- incorporating feedback mechanisms to provide information to the system; and
- revisualizing the role of graduate schools.

Ph.D. Production

A major indicator of the inadequacies of graduate education in its current state, writers pointed out, is that the number of Ph.D.s produced greatly exceeds the number of positions available in academe. "It cannot be overstated," one person wrote, "that an overwhelming majority of graduate students will not find work in academia" (Bo Hammer). Others considered the problem

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from a different perspective; that is, many graduate students do not ***intend*** to work in academe. From this viewpoint, writers noted that graduate faculty are preparing many students for jobs they do not want. Based on these observations, writers advanced two perspectives: many argued that today's Ph.D.s ***are too narrowly trained***; and some argued that graduate education ***is producing too many*** Ph.D.s.

Those who took the view that Ph.D.s are too narrowly trained offered many suggestions on how to broaden the educational experience of graduate students. These suggestions mainly addressed two overarching goals: (1) "prepare graduate students more appropriately for their diverse professional futures" (Bo Hammer) and (2) educate graduate students about the range of career possibilities-make them informed participants in their own education. Suggested solutions included

- developing students' professional skills;
- providing various types of career services to inform students of career possibilities;
- preparing faculty to be better and more informed mentors; and
- through successful industry/university networking, providing students with internships that fit their education and research needs.

The few people who took the view that there is an overproduction of Ph.D.s suggested that graduate programs change their admissions policies to manage the number of Ph. D.s being produced. For instance, one person suggested that "an alternative may be to cut back on admissions to Ph.D. programs to avoid a 'glut' of Ph.D.s and to funnel students interested in nonresearch careers into different disciplines or different programs" (Tony Goldberg).

In particular, many writers suggested that graduate education needs to rethink how it values master's degrees, as well as develop new master's programs to meet industry needs. While this view was not directly correlated with the view that there is an overproduction of Ph.D.s, it complements that view, in that it provides more options for postbaccalaureate education. Others suggested that an effort to re-engineer degrees to better meet the needs of students and society would help address the issue of overproduction.

DPSC **citations**

Career Information Services – Sloan Foundation (***DPSC*** pp. 7-8) [see p. 18]

Physics/Business Courses – City University of New York (***DPSC*** p. 53) "Two complementary projects aimed at enhancing future employment for Ph.D. physicists, scientists, and engineers were initiated at the City University of New York. The program is funded by a grant from the NSF with Professor Brian Schwartz as principal investigator. The first project is a local pilot program consisting of four supplementary minicourses entitled 'Scientific Career Management,' 'Communication and Multimedia Skills,' 'Computer Skills Used in the Work Place,' and 'The Business and Economics of Science and Technology.' . . . The second project is an outreach

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program in which the PI and others schedule a site visit to evaluate the career guidance, coursework, and environment at various physics (science) departments. The site visit includes a colloquium on employment situations plus meetings with faculty and graduate and undergraduate students."

Doctor of Chemistry – University of Texas at Dallas (*DPSC* pp. 74-79) [see pp. 18 and 34]

Professional Skills Development

I think that more needs to be done to introduce the diversity of possibilities for Ph.D.s before sending them out in a specific internship. I would like to see more career development happen, à la Preparing Future Professionals, before presuming that one particular route to a career is best for any particular graduate student. Jan Smith

Many writers noted the importance for graduate students to have opportunities to gain professional skills. Programs should help students develop skills, including teaching, communication, public speaking, organization, research, cover letter writing and CV preparation, job search, technical writing, team and interdisciplinary work, and networking. However, comments regarding the use of resources to provide these types of programs highlighted a dichotomy in the opinions about how to best serve the needs of graduate students. Some advocated expansion of programs that emphasize teacher training, while others sought expansion of programs toward business and industry skill development. Virtually all of these comments were in response to "preparing the professoriate" programs. Many, noting that most Ph.D.s do not get jobs in academe, argued that university resources, in general, were disproportionately spent on "preparing the professoriate" programs. These writers urged that more resources be geared toward programs that enhance skills needed in business and industry. The following writers articulated these concerns:

> It still appears that concentration is very much centered around the preparation of students for faculty positions. The overwhelming evidence is clearly that very few students (especially in engineering) have an interest in these. (William Clark)

> If I were a member of the "educational infrastructure" panel, I would have asked the "preparing future faculty" speakers why they find additional resources for the 25% of Ph.D. students who will obtain faculty positions and neglect the professional development of the other 75%. (Lynn Melton)

DPSC **citations**

Dual Degree Programs in Veterinary Pathobiology – University of Illinois (*DPSC* pp. 9-13) [see p. 24]

Physics/Business Courses – City University of New York (*DPSC* p. 53) [see p. 54]

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ScienceWorks – University of Nebraska-Lincoln (*DPSC* pp. 61-66) "ScienceWorks is an NSF-funded project combining outreach to the public with improving graduate student education and skill development. . . . Participants develop, present, and evaluate outreach modules to students and the general public. Participation in these activities provides students experience communicating with nonscientists, improves their oral and written communication skills, provides opportunities to participate in interdisciplinary teamwork, and exposes them to proposal writing. . . . Student participants overwhelmingly cite their experience as a strong positive factor in having obtained a job after graduate school."

Doctor of Chemistry – University of Texas at Dallas (*DPSC* pp. 74-79) [see pp. 18 and 34]

TA and Teacher Preparation

[With respect to the Future Professoriate Project] we know that graduate student departments mobilized and said, "You can't exclude us from this." The master's "We really want to be a part of this." We have had master's students participate Professoriate Project. [We have interviewed] alumni who have gone on to other p have gone into research labs, some into business and industry-about 20% of our in faculty positions. Some of them are master's students, and they, in fact, said it most valuable experiences in their graduate career. So it's giving us cause, throu improvement, to go back to departments and say, "If this opportunity is valuable, we make it accessible to more students in departments?" Stacy Lane Tice

Some participants advocated for policy changes that would make certain types of training programs mandatory. For example, a few argued that there should be teacher training programs for all TAs before they begin their job responsibilities. Some suggested that instruction on proper mentoring relationships and "teaching effectiveness seminars" should be part of a TA's training.

Many commented on the value of programs geared toward preparing graduate students for careers in academe. A few writers made the point that the types of skills gained in those programs are needed in business and industry as well:

> "Preparing the professoriate" programs need not be posed as such specific, focused training sessions; many of the skills gained (especially organization, communication, public speaking) will be invaluable regardless of ultimate career decision.

Some writers argued that the professional skills required for students going into business and industry can be gained through a "broad set of experiences," including extracurricular activities, interdisciplinary programs, and programs that have industry involvement. One writer highlighted the importance of industry involvement, but noted it need not take the form of an internship. "However, programs developed for industry do need industry involvement [of some form]" (Patrick Mulvey). Another writer described a survival skills program that gives students valuable information and help:

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> Much has been made in the sessions this morning and in general [discussions], concerning programs for preparing the faculty. Preparing the "professionals" has not received the same attention. This must be addressed, and I was pleased to hear it is starting to be addressed at some institutions. At WEU we have initiated survival skills programs aimed at giving students the information and help that they need while in graduate school and to assist them in preparation for careers in general. (Many of the needed skills are not just for faculty—e.g., communication, lecture presentation, writing skills are needed.) (Gordon Melson)

And more general suggestions, with respect to professional skills, included networking and exposure to professionals in the field through attendance at such events as conferences and professional society meetings. As one person wrote: "For professional growth of graduate students, provide funds for travel to professional meetings-establish them as independent researchers." (Narayan Bhat)

DPSC **citations**

Speaker Series – Cornell University *(DPSC* pp. 67-68) [see p. 43] "The graduate1 students themselves have found that speaking to an undergraduate audience gives them a solid practice session for any job talk they may give when the graduate."

Future Professoriate Project – Syracuse University *(DPSC* pp. 146-152) [see p. 48] "The FPP established three initiatives to more comprehensively prepare teaching assistants for academic careers. A series of Faculty Teaching Mentors Seminars aimed at fostering disciplinary and interdisciplinary thinking among faculty mentors about issues and practices essential to the preparation of future professors. . . . A new appointment for graduate students called the teaching associateship, entailing more advanced and independent teaching responsibilities under the guidance of a faculty teaching mentor. . . . A new credential called the Certificate in University Teaching, to be awarded at graduation to those teaching associates who successfully complete a program of professional development evidenced by the production of an effective teaching portfolio."

Instructing Science TAs on Using Writing to Enhance Teaching and Learning in Undergraduate Science Laboratories -Western Washington University *(DPSC* pp. 153-157) "This project was conceived in the summer of 1996 at a meeting that included the director of the Writing Center and the Dean and Assistant Dean of the Graduate School. . . . The workshops . . . addressed the following topics: Designing effective writing assignments (both formal and informal); responding to student writing (peer and instructor feedback); grading writing (including creation of rubics)."

Preparing Future Faculty – University of New Hampshire *(DPSC* pp. 180-18 1) "Under programs offered by our Graduate School, doctoral students interested in an academic career have the opportunity to add to their Ph.D. a 12-credit Cognate in College Teaching or earn, as a dual degree, a 32-credit Master of Science for Teachers degree with major in College Teaching. Each program provides the student with formal preparation in research involving teaching and

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learning (General Core), the research from their specific field or discipline related to teaching and learning (Field and Disciplinary Studies), and formal supervised experience teaching (College Teaching Praxis).

Preparing the Professoriate – North Carolina State University (*DPSC* p. 187) "Preparing the Professoriate is a program that gives faculty and doctoral students the opportunity to engage in a significant mentoring activity for an academic year. It is a central component of NC State's attempt to enrich and improve the way in which graduate students are trained at this university."

Career Development

Access to information that allows graduate students to make informed decisions about their education and their future careers was also noted as important. Writers suggested that students can gain this information from career service centers, seminars and workshops, faculty/student mentor relationships, professional societies, and exposure to industry. Specific topics included "integrity in research, career choices, relative merit of teaching and research, and collaborative research" (Narayan Bhat); "awareness of career paths, and the career outcomes of recent graduates" (Patrick Mulvey); "uses of [various] graduate degrees"; and faculty's view on "what the Ph.D. degree is for."

Many writers offered various strategies for preparing graduate students for future careers, and for providing them with important information. For example, one person suggested that there should be career development programs offered on a "noncredit or pass/fail basis; appearing on transcript for graduate students across the university" (Donald C. Retizes). Some recognized the importance of bringing administration on board to further students' career development options. Universities should develop "ways to impress administration that a career services office for graduate students and postdocs is important."

Some reminded the community to look for existing resources and expand upon already existing programs and services. As Timothy Donohue wrote: "On a more centralized campus, the most appropriate strategy for infrastructure development might be to expand on already existing centrally provided services (e.g., career services) to include graduate and postdoc concerns." Another person wrote:

> There are resources on most campuses for career development/professional development. If there exists a centralized placement office, there may exist the expertise and will to serve graduate students. The directors of these offices should be contacted and conversation initiated to determine how best to make services available to graduate students. Supplement existing series/programs of professional development seminars and career assessment seminars; involve the development office in career/professional development workshops.

Some writers suggested that networking can enhance a student's awareness of career opportunities. Alumni were identified as especially good contacts for providing further contacts and invaluable career information:

[Facilitate] some type of industrial contacts through alumni networks, the Internet, etc. (Patrick Mulvey)

Career explorations at the graduate level would be invaluable. One of the best suggestions I heard was that of inviting graduates of the program who have entered alternative careers to come and share their experiences with current students. (Scott Sewell)

DPSC **citations**

Career Services for Doctoral Students in Science and Engineering - University of Pennsylvania (*DPSC* pp. 1-6) [see p. 18] "University of Pennsylvania Career Services has a long-standing commitment to career planning for graduate students. Services include individual advising . . . 'The Academic Job Search Handbook' . . . fellowship information . . . programs and workshops . . . electronic communication . . . job listings . . . career library . . . files of letters of recommendation . . . alumni contacts . . . on-campus recruiting."

Career Information Services – Sloan Foundation (*DPSC* pp. 7-8) [see p. 18)

Engineering Education Scholars Program – University of Wisconsin-Madison (*DPSC* pp. 14-15) [see p. 40]

Graduate Education Enhancement Program for Underrepresented Minority Students in the Computational Sciences – Rice University (*DPSC* pp. 16-23) [see p. 24]

Physics/Business Courses – City University of New York (*DPSC* p. 53) [see p. 54]

Technology: Education and Commercialization (TEC) Program -North Carolina State University (*DPSC* pp. 126-128) "Through North Carolina State University's Technology: Education and Commercialization (TEC) Program, graduate and postgraduate students from business, engineering, science, and other nontechnical fields form interdisciplinary teams to screen, assess, and develop technologies and products for commercial applications; Advised by experienced faculty members and business professionals, the student teams follow a year-long systematic approach to formulate product concepts; to consider technical, legal, financial, marketing, organizational, and manufacturing issues; and to develop commercialization strategies."

Faculty Mentors

Yesterday, those of you who came to the session that I was in and heard my presentation, heard me start off by saying how postdoctoral fellows were different from graduate students. But today I think I would like to start by saying how we're similar. We are both still being trained, and I think that is a very important point that people seem to have forgotten. We also need the support structure that graduate students have, and we don't always have that. And more importantly, we

need mentor-ship. Probably more so than graduate students, because we're entering the "career phase" of our training. The other important point that we tried to stress is that, as postdocs, we 're often called upon to act as unofficial mentors for graduate students, and so our satisfaction with our mentorship will in turn translate into the graduate students' overall satisfaction with their graduate program. . . .We [attempted] to identify other problems, and we did this with a very comprehensive survey of the existing postdocs that we knew about at Einstein. . . . [We found an] astounding fact- the overwhelming problem that every postdoc mentioned was with mentorship. Paula Cohen

Some writers felt that faculty mentors are an important component of a graduate student's educational experience, and, thus, mentoring should be emphasized:

> The heart and soul of graduate education is the **mentored** learning experience. How are faculty prepared to assume this role and how are graduate students prepared to engage in this "new" way of being in school? Do we have faculty development programs to help new (and older) faculty identify and develop effective pedagogies that work for their personalities, science, and **teaching** goals? (Paul Ilecki)

Writers emphasized the importance of ensuring that faculty mentors are qualified to deal with topics such as research integrity, career choices, collaborative research, and "the relative merit of teaching and research as a career choice." Yet, these writers realized that often faculty are not prepared for this responsibility. Accordingly, various Forum participants urged schools to provide educational opportunities for faculty to learn about the "realities of the job market and the graduate student experience. . . . [Graduate schools should] find ways to help faculty assume responsibility for mentoring, counseling, advising, and nurturing students and their learning." To these ends, others urged that schools "involve faculty on panels and encourage faculty to attend campus career fairs." One person wrote:

> I would like to see graduate schools and federal agencies both enable and require accountability for better mentoring of graduate students by faculty-in their research, in helping students explore broader career options, and in developing those skills that would make students morelcompetitive in their job search.

There are many faculty who are open to doing things differently, but don't know how," one writer noted. A few writers argued that one thing faculty lack is information about the current job market-"faculty are largely unaware and inexperienced with professions beyond the university. (Bo Hammer) Others wrote:

> [Faculty] tend to have information relevant to career/job prospects for when they were emerging Ph.D.s in a vastly different world. This information is outdated and potentially harmful. Advisors need to be educated in this aspect to serve/mentor students well. (Mark **VanOverbeke)**

> I agree with Dr. Schwartz that one of the greatest problems in good education is that there is not an adequate feedback loop to the faculty about the realities of the job market. (Max C. Poole)

> The most riveting discussion, in my view, was triggered by Brian Schwartz's realistic) portrait of the true diversity of career paths for science and engineering graduate students. This provoked lots of

realistic discussion of the need for universities to provide better mentoring mechanisms and to press faculty in these directions.

The following people offered yet other strategies for meeting the mentoring needs of graduate students, postdoctoral students, and junior faculty:

> Apparently, in the science disciplines, the interactions between the faculty advisor and the student or the postdoctorate could be made more effective by using meetings during technical conferences, discussions during lunch or dinner, laboratory meetings with undergraduate students/ (Arturo Bronson)

> The need for mentoring does not stop with the end of the Ph.D. sequence, but [continues] through postdoc and even through junior faculty years. Departments can recognize this and set up relationships built into load assignments. The result is more successful career development with fewer failures at each stage. Also, the next generation of research advisors will be mere attuned to the mentoring process. Strategy: build mentoring into department expectations, discuss the problem with faculty, identify key faculty, get them to buy in, then institutionalize/publicize. (Walter C. Adams)

A few were not so positive about the prospect of improving faculty mentoring. The writers quoted in the second part of the previous Faculty Culture section expressed concerns related to effecting change in the faculty-for example, "Major professors are too concerned with the bottom line-research-to carefully assess a student's strengths and weaknesses in order to give career advice. Often the major advisor at best can suggest a company or school that is doing 'good work' without any recognition of the student's needs."

***DPSC* citations**

Graduate Education Enhancement Program for Underrepresented Minority Students in the Computational Sciences – Rice University (*DPSC* pp. 16-23) [see p. 24] "The Sloan Program, directed by Richard Tapia, Noah Harding Professor of Computational and Applied Mathematics, targets four departments. . . . For his long-standing work in mentoring, Tapia has won numerous awards including AAAS's 1998 Mentor: Lifetime Achievement Award and, in 1996, the NSF's Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring."

Technology: Education and Commercialization (TEC) Program – North Carolina State University (*DPSC* pp. 126-128) [see p. 59]

Industry Internships

Many schools are working on developing "professional" or industrial master's or even doctoral programs, many of which involve internships. What are the possibilities for reform in

curriculum, grants agency policy, and faculty attitudes to make possible educationally and professionally relevant internships for students? Lisa Brandes

Many writers reminded us that the greater proportion of graduate students do not become faculty. They therefore called for a "decreasing focus on academic careers as the be-all end-all of graduate education" (Robert Rich). For graduate education to become more relevant to a large number of students, they argued, "it is important to include and involve industry when teaching our graduate students. We need to work with industry as partners to develop meaningful, broad-based master's and Ph.D. programs" (D.C. Wiggert among others). Some writers;, including some students, testified to the benefits of a good industry/university partnership and direct research experience with industry:

> Having gone through the Idaho State Waste Management Program, obtained an internship in which I completed research toward my thesis, and obtained a position in industry directly related to my research and schooling (as a result of the partnership between Idaho State University and Idaho National Engineering and Environmental lab), [I can say that] the program was a huge benefit to my career. (Kastli Schaller)

> As a graduate student at NCSU, I see many examples of cooperation between industry and the university. Both universities and companies are looking for ways of mutual development and research. The logistical problem of matching sponsoring industry with appropriate students and research areas is one that will have to be attacked on an individual departmental basis in the university and on a project basis in companies. It is extremely valuable for students to obtain actual experience and receive research credit at once. It is worth the effort to work out the legal, etc., requirements of this kind of cooperation. (Tiffany Barnes)

> From my visits to projects attempting to implement programs preparing students for diverse careers, it is clear that students who do work in industry are almost always enthusiastic about how their horizons have been broadened and their awareness of possibilities increased.

A few warned that industry-based programs should be careful not to train students too narrowly. As Tiffany Barnes wrote, "One of the problems with training students in graduate schools for particular industries is that the student may not necessarily be flexible enough to adapt to changes in the research needs of industry. [We] need to encourage the concept of life-long learning."

The following writers offered specific strategies for designing an industry-based curriculum:

> We have introduced a new course-Introduction to Industry Practice-that includes organizational structures, operations, management regulations, GLP, entrepreneurialism, business plan, and mock interviews at industry site. Fellows need career counseling, alumni networking, CV writing skills, and grants workshops. We have initiated a biomedical alumni network center (BANK) for depositing and retrieving information on career opportunities. (Thomas Yorio)

In developing the DChem program, we asked our industrial friends, "What are your jobs like?" and designed a curriculum to produce successful industrial "problem solvers." Lynn Melton

DPSC **citations**

Doctor of Chemistry – University of Texas at Dallas (*DPSC* pp. 74-79) [see p. 18]
"In the mandatory 9-12 month Industrial Practicum, a student works full time at a company site, usually on a proprietary problem, which has been chosen to benefit the company and to push the student's growth as an industrial problem solver."

A Ph.D. in Technology Management by Consortium - Indiana State University (*DPSC* pp. 112-1 17) [see p. 22]

Programs for Industrial Mathematics – University of Minnesota (*DPSC* p. 125) [see p. 23]
"The Institute for Mathematics and its Applications initiated its Industrial Postdoctorate program over six years ago. Industry, in partnership with the Institute, sponsors a postdoc for a 2-year appointment in which the postdoc devotes half of his/her time on an industrial project at the company."

Biotechnology Training Program – University of Wisconsin-Madison (*DPSC* pp. 134-1 38) [see p. 24] "[Students] partake of an ~12-week internship, often in their first or second year of graduate school. In addition to providing first-hand exposure to a new research setting, this internship allows students to see other cross-disciplinary principles/teams in action."

Master's Degrees

The audience asked the hard questions about strategies for change in serving students. One participant asked, "How does one define success or failure? Should a student be deemed a failure for stopping at the master's level or taking a position in industry? Is a nontraditional career a sign of failure?"

Many writers pointed out that master's degrees, and options to pursue nontraditional career tracks, are often viewed with a stigma. Some noted that master's degrees are typically thought of as consolation prizes for those who choose not to, for whatever reasons, complete their Ph.D. program. These writers urged that the value of a master's degree be reconsidered. One writer advised the following:

> Also of value would be a conscious effort to remove any stigma from terminating graduate education at the master's degree. This level of education has many productive purposes. Perhaps Brian Schwartz's notion of empowering students is a good way to do this-or start doing it.,

Writers urged not only that we revalue master's programs, but that we rethink and improve them to even better meet the needs of business and industry. The following writers made these points:

> There needs to be more emphasis on the professional master's degree to meet industry needs. Curricula for such degrees need to emphasize business and industry needs while ***not*** compromising

the fundamentals of graduate education-acquisition of knowledge and development of the ability to think critically. I applaud the support of nonacademic career options. (Terry Schaefer)

I suggest we think about dramatically reducing the number of Ph.D. students to match the job market they are being trained for and re-engineering degrees to better meet the global society's current and future needs. If academic institutions don't do this, someone else will. (Kathy Luker)

Despite the observation of many that master's degrees are not generally valued in academe, some writers noted that they are definitely valued in business and industry. The following writer makes the point that master's degrees are becoming more valued in a changing job market, and also that they do not replace the Ph.D.:

A bachelor's degree used to be sufficient for a professional position in many fields, e.g., chemistry, geosciences, biological sciences, engineering. With academic inflation plus the increasing complexity of work, a master's is now necessary and therefore the proliferation of targeted master's programs in, e.g., biotech and environmental sciences. These programs do not replace the Ph.D., nor should we encourage more people to get master's degrees and fewer to get Ph.D.s. It depends on what type of position a person wants.

Writers noted that there are schools currently involved in redesigning some of their programs. Many schools are working on professional, industrial master's, and doctoral programs, many of which have internship components. A few writers reminded us that engineering schools, especially, have experience in redesigning programs and curriculum:

Graduate programs are interacting more and more with business and industry. Engineering schools are required to respond to the needs of industry. Engineering schools have initiated a large number of professional master's degrees and short courses. (Narayan Bhat)

***DPSC* citations**

Dual Degree Programs in Veterinary Pathobiology – University of Illinois (***DPSC*** pp. 9-13) [see p. 24]

Hazardous Waste Management Program – Idaho State University (***DPSC*** pp. 94–102) [see p. 223

Industrial Interdisciplinary Program – Virginia Polytechnic Institute & State University (***DPSC*** pp. 103-106) [see p. 22]

Professional Master's Degree Program in Geosystems – Massachusetts Institute of Technology (***DPSC*** pp. 118-124) [see p. 22]

Student Empowerment

[The Future Professoriate Project] also became a social movement, as graduate students became involved. They did much of the proselytizing for the department. We had one of the faculty leaders in the management department stand up at one of our faculty liaison retreats last spring and say, "Well, I finally did it. I cracked the toughest nut. We have the person that we've been hoping to be involved in the Future Professoriate Project come and decide to join the project. It was a very difficult year but I finally did it." And everybody looked at him and said, "How? How did you do it?" And he said, 'A graduate student asked him." Stacy Lane Tice

[The postdoctoral survey results indicated] other problems-quality of life issues that needed to be addressed, such as housing and benefits and the general status ofpostdocs within the school community. But one of the first things that we [postdocs] tried to do was to acknowledge that we were responsible. If we felt in some way politically disenfranchised within the community, it was our responsibility to change it. We couldn't really expectfaculty to sit back and say, "Yes, it's all our fault, we're going to make things right." So one of the first things we did after the survey results came out was to form subcommittees. We decided that we had so many problems to tackle, we had to tackle them simultaneously. Paula Cohen

Many of the solutions and strategies previously discussed-preparing faculty to be better mentors, providing career services, providing networking opportunities, providing exposure to business and industry-act to inform students and help them make decisions about their education and future careers. Many writers also suggested that it is important for students to have a voice in graduate education reform-some noting that the student voice was lacking in the Forum discussion. While recognizing the important role of administration and faculty, and the valuable support afforded by the graduate school infrastructure, they also noted the equally important role of the graduate student. These writers argued for "widespread and active involvement" of students in graduate school governance. They suggested that external funding sources consider student input, one person writing, "Maybe NSF should worry more about student buy in, not just faculty buy in, in proposals for training Ph.D.s" (Mary Sladek). Others wrote:

> Speaking as a graduate student, one very important point is that graduate students and postdocs must realize that they have the ability to lead change themselves. While the involvement of the institutional infrastructure is critical in affirming that serving students' needs is a critical part of graduate education, graduate students must understand the power they have to direct change.
>
> I strongly advocate that graduate administrators and faculty entertain student proposals for re-inventing graduate student support programs that will help students find jobs upon completing degrees. Student-planned and designed career counseling services for master's and Ph.D. students seem particularly needed. Also needed are imaginative and innovative student-planned/university-supported interdisciplinary activities. (Edwin R. Gerler, Jr.)
>
> Students need to be part of the innovation process. . . . Administration and faculty need to listen to what kind of changes students want and involve students in the change process. Teacher-training

programs need to have a peer-led workshop component (or something similar). . . . Grad students are often (in my experience) the impetus and primary drivers of change. (Donnasue Graesser)

I want to emphasize that much of the conference has overlooked grad students themselves as agents for change. My own program, . . .is entering its seventh year of existence. For the first six years, the only "supervision" we received came when the university delivered our budget allocation. Otherwise, we were entirely staffed and supervised by grad students. Period. Now that we are part of [an administrative office], we have support and supervision from a wonderful graduate education professional, so our program will grow even more. But my point is that I would urge conference participants to look at programs that grad students might already have developed on an ad hoc basis that could be excellent candidates for institutionalization. (Kristen Welsh)

Some noted that the way graduate students are funded is not always in their best interest. They reminded readers that it may not be realistic to expect graduate students who receive traditional funding support tied to a professor's research to have much choice and power with respect to their education:

One fundamental problem about the funding structure for graduate education is that students are recruited into grad school and funded to do work on a professor's grant, but not to receive training appropriate to the demand of society and the economy for trained scientists. Unlike med school or law school, for example, graduate education is funded by the need for labor to work on federal grants, not the need for students to be trained for a future career that will be available1 to them soon after graduate school.

A change in funding structure [is required] to facilitate the [necessary] faculty attitude changes. [Funding support should move] away from funding faculty for research as a mechanism of graduate student support. [A separation of] research and graduate student support is necessary. Training grants are a first step, but I think more separation is required. (Mark Maroncelli)

Several writers felt "portable funding" would allow graduate students to have more control over their education. They argued that students should receive "direct grants in order to allow changes in study direction." Some suggested that teaching fellowships could be awarded.

Individual graduate support would be a great idea for students who have ideas they would like to carry out in graduate school. For example, the student should write a proposal for their funding. (Tiffany Barnes)

The idea of portable grants is very appealing. Therefore, the student is not entirely dependent on the major advisor for financial support.

However, a few were concerned about the implications of portable funds for graduate students:

I have concerns about portable funds. In some instances, they open doors and create opportunities, but should not a department invest fully in its students? Would department money facilitate faster integration into the department?

***DPSC* citations**

Graduate Experience Project – University of Michigan (***DPSC*** pp. 25-29) [see pp. 24 and **43**]

Graduate Student Research Symposium (GSRS) – Yale University (***DPSC*** pp. 30-34) "The Graduate Student Research Symposium (GSRS) is an annual forum for the exchange of ideas between graduate students in the biomedical and biological science **departments** of Yale University. . . . Each year more than 30 graduate students volunteer to organize GSRS, forming six committees responsible for specific aspects of the symposium. The hard work **provided** by these committees is coordinated by the GSRS organizing committee, a group of 8 to 10 graduate students. GSRS organization provides an important opportunity to develop leadership, administrative, communications, and promotional skills necessary for success in academic science and many other careers."

McDougal Graduate Student Center – Yale University (***DPSC*** pp. 43-47) [see p. **43**] "The Center succeeds to the extent that students see it as 'theirs' by developing a sense of ownership."

Leveraging Funds

Providing teaching fellowships as well as research fellowships is another strategy that we have found to be quite promising. Dale Johnson, our previous dean, actually put this program into effect. We took a $500,000 [alumni] endowment . . . and instead of [using it for] research fellowships we [created] teaching fellowships. Now, nine graduate students a year are funded, after an all-campus competition, to spend a quarter creating some kind of teaching product, working with a mentor either on our campus or at any one of the surrounding campuses. This visibility for teaching fellowships has made a great difference in how people view the whole act of preparing for teaching, especially for those going on into the professoriate. Jody Nyquist

Many writers noted that funding can be used as leverage for initiating change. Writers supported the "idea of government agencies mandating some of [the proposed] changes" (Arthur B. Ellis). For example, one person argued that "the National Science Foundation, the Department of Energy, etc. should include or require industry internships as part of the fellowships they provide for graduate training" (A. Ravindran). And another wrote, "One suggestion I've heard is that change should be a requirement set by, for example, National Science Foundation and National Institutes of Health. I believe this would facilitate speeding up necessary changes and provide an incentive to change the most difficult-to-convince part of the hierarchy: faculty."

The following quotes illustrate think piece writers' views that the funding structure supports and perpetuates certain faculty attitudes, and that a change in funding structure can affect a change in faculty attitude regarding graduate student training:

A faculty member needs grants to get tenure. If the R01 and training grants go to those that produce the most papers and not those who give graduate students and postdoctoral fellows needed skills, we will continue to have training that is nearly 100% based on bench work-often solitary work. By changing training grants, and perhaps R01 grants, to reward those whose students do internships or work on multidisciplinary programs, then the incentive to bring money to the university would involve both a factor of modern training and bench science. (Chris Gaj)

The areas of faculty education, encouragement, and incentives need to be explored, particularly by funding agencies. On my campus, faculty pay a great deal of attention to the criteria and interests of the various funding agencies. If faculty see their funding tied to these various support systems for helping graduate students professionally as they are gaining content knowledge, then the potential for success is much greater. (Julia S. Austin)

Not all writers focused on funding from external sources. For example, the following person urged graduate schools to use their own funding to leverage change:

Graduate schools can foster and encourage change by strategic (and competitive) distribution of funds. Examples are fellowship competitions, graduate program support (for enhancing quality and diversity), recruiting funds, program excellence funds. (William Clark)

DPSC **citations**

Interinstitutional Multidisciplinary Ph.D. Programs – University of Puerto Rico (*DPSC* pp. 35-37) [see p. 31] "Research capability of the Ph.D.s in both Chemistry and Chemical Physics has also been expanded by the creation of a Center for Materials Characterization with funds from the state government, as well as federal funds. . . . The Center saves local industry close to $5 million as a result of the services provided. It generates income of about $200,000 per year."

Dayton Area Graduate Studies Institute – Wright State University (*DPSC* pp. 69-73) [see p. 33]

A Ph.D. in Technology Management by Consortium - Indiana State University (*DPSC* pp. 112-117) [see p. 22]

Bio-Med Interdisciplinary Programs – Emory University (*DPSC* pp. 129-133) [bee p. 31] "After learning of the potential incentives for establishing cross-disciplinary interactions among faculty,, he [new dean of the Medical School] decided to promote the establishment of interdisciplinary graduate training programs. . . . Initially, approximately 60% of the chairs involved were reluctant to accept the idea. Several suggested that a better approach would be to develop a mix of both interdisciplinary and departmentally based training programs. However, this idea was not pursued because the medical school dean indicated that he would not support any free standing departmentally based graduate training program. . . . An additional factor in generating faculty and chairperson support was the significant increase in resources committed by the University to the Division."

External Funding Limitations

Like many of the other programs here, the Biotechnology Training Program at UW-Madison started out with a seed money grant, and of course the problem with seed money grants is how to institutionalize the program. One may have a renewal period in terms of a second grant, but then the issue is always, "When is the university going to begin to pick up the tab?" The first thing one can do is to create a quality program. The satisfaction of the student and faculty participants is absolutely crucial in terms of anyone wanting to continue it. But second, it is important to solicit from the very beginning support from chairs and deans and provosts. Even if they are not putting money into it, it counts that they are willing to verbally support it at any one juncture.
Timothy Donohue

Some were concerned about the viability of a change strategy that depends primarily on start-up funding from external sources. As one person asked, "How many graduate schools have the resources to manage interdisciplinary Ph.D. programs until they are spun off? This may be a large burden for many" (Richard L. Lintvedt). The following individuals articulated this problem:

> I am concerned about the difficulty of finding long-term funding for initiatives that are initially supported by temporary outside funding. Thus if GAANN funding is used as an incentive for a department to develop interdisciplinary programs, this incentive will vanish in a few years. One must hope that at that time the success of the program and institutional finances will allow its continued funding. I don't know how to guarantee success. Having a program that can be continued at a low level of support, pursuing fund-raising opportunities, and continual administrative support all seem to be helpful strategies. (Robert Wilson)

> The experience of attempting change in the institutions I have visited in the course of my work for NSF suggests that even programs that advocate innovative changes do not necessarily get them. Panelists frequently fund proposals that make no pretense of fulfilling innovative programs. In the real world of implementation, PIs and faculty often do not follow up on their proposed plans. In many instances, pressure from the funding organization is not sufficient to encourage serious efforts to meet program goals.

Some questioned the capacity of "funding as leverage" strategy to meet all the needs for change articulated at the Forum:

> Funding mechanisms (e.g., National Institutes of Health interdisciplinary training grants, National Science Foundation Integrating Graduate Education and Research Training grants) can provide incentives for cross-disciplinary and cross-profession collaboration. Currently, however, they provide little in the way of incentives or demands for other aspects that have been highlighted in the meeting (e.g., training in communication skills, internships in industry or other settings). (Michael Smyer)

A few questioned whether it is realistic to expect certain kinds of education reform goals to be written into a federal agency's requests for proposals, as these goals may not be aligned with the agency's mission.

> One concept mentioned in the Forum discussions that I do not believe can work is a requisite inclusion of specific training objectives (PFF, teaching, etc.) on all research grants. The federal

agencies and legislators will not accept this type of training as [suitable] for appropriations to basic research efforts. (Timothy Mulcahy)

Will funders, particularly federal agencies, be as satisfied if a significant percentage of students supported go into more traditional careers, particularly nonresearch careers?

Writers offered yet other reasons why proposal requirements may not be a viable change agent:

The suggestion was made that funding agencies could motivate reform by including it as conditions for research grants. This is a good idea, but won't work as the people who do peer review are usually the same people who focus on research to the exclusion of other things.

I heard a lot of "passing the buck" to funding agencies who should force the change through modifying their funding practices. But I think anything forced onto programs is bound to fail. (Jim Freericks)

DPSC **citations**

Interinstitutional Multidisciplinary Ph.D. Programs – University of Puerto Rico (*DPSC* pp. *35-37)* [see pp. 31 and 68]

Speaker Series – Cornell University *(DPSC* pp. 67-68) [see p. 43]

Future Professoriate Project – Syracuse University *(DPSC* pp. 146-152) [see p. 48] "Universitywide enthusiasm and support was evident. It was in this context, just as the grant expired, that . . . the new Director . . . was faced with [the challenge to] find new—preferably permanent-sources of funding. . . . None of the [subsequent] initiatives could have been sustained without funding; with the active support of Dean Howard Johnson, the vice chancellor of academic affairs base-budgeted the project with enough funds to sustain all aspects of the woiect."

Reward Structures and Faculty Incentives

Some people wrote that they would like to see a change in the faculty reward system-one that would encourage faculty to become involved in these various initiatives. In particular, they wanted the reward system to provide incentives for faculty to get involved in industry, multidisciplinary work, and mentoring. As one person noted, "The infrastructure (support as well as resources) is often not available and neither are the incentives. And it is even more difficult to get people to change if they do not see anything 'in it' for them" (Maribeth Watwood). The following quotations articulate the need for faculty incentives:

In both sessions I was impressed with the variety of approaches to achieving a more student-centered educational experience that was driven less by the research agendas of faculty and more by the need to prepare students for future careers-academic or otherwise. However, all of these approaches—

even those involving the faculty in the change process-seemed not to address the reward and incentive systems for faculty that drive their insistence on having graduate education serve their research agendas. Specifically, [we need] a more balanced reward and incentive system for faculty that rewards involvement in preparation of graduate students for academic careers as well as professional careers in industry and/or federal research facilities. Also, [we need] a greater emphasis on faculty incentive reward systems that look at faculty members' own excellence in teaching and in their interaction with industry and government research sectors. (Sheila Kearns)

Faculty are very open to change. In particular, assistant professors are underutilized by administrators, funding agencies, postdocs, etc. Instead of being encouraged to get involved, new faculty are forced to wait on the sidelines until they get tenure. If administrators worked to change this, and if funding agencies gave new faculty incentives to be involved, change would happen faster.

The following writers suggested types of incentives that can help faculty come on board with change initiatives:

Faculty, in large part, drive these industrial collaborations. Therefore, faculty incentives are very important, and that does not just mean writing a fat check. Rather, incentives that truly facilitate faculty in their research, publication, and tenure pursuits would have the best chance at really stimulating successful collaborations. These incentives would also facilitate the shaping of positive faculty attitudes regarding student internships in industry. (Maribeth Watwood)

The need for strong faculty involvement is very important and needed. If time permitted-I would have added more on how we've been able to move change with faculty through (1) pay for performance; (2) involvement in strategic planning; and (3) the way in which resources are distributed. (Bernice Bass de Martinez)

Reward faculty initiative with future release time. A big problem is that the system abuses those who are willing to invest time in implementing programs with more responsibilities (more and more is done by fewer and fewer).

DPSC **citations**

Dual Degree Programs in Veterinary Pathobiology – University of Illinois (*DPSC* pp. 9-13) [see p. 24] "The benefits to the existing programs have been in the improvement in the general quality of the entering classes of graduate students, increasing department funding of graduate education and a stimulation of an environment of quality medical research graduate education."

Graduate Education Enhancement Program for Underrepresented Minority Students in the Computational Sciences – Rice University (*DPSC* pp. 16-23) [see pp. 24 and 61]

Doctor of Chemistry – University of Texas at Dallas (*DPSC* pp. 74-79) [see pp. 18 and 34) "In 1994 the Advisory Committee recommended that, since the 'bugs had been worked out' (mostly true), the DChem program should expand from 6-8 students admitted per year to 15-20 students. This meant an expansion of both the student recruitment efforts and the availability of Industrial Practicum opportunities. A faculty member was given half-time release from teaching

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responsibilities and travel funds. . . . The intense initial two years, the experience gained in the Industrial Practicum, and the overall DChem program structure and student quality have made the students' movement into career industrial positions exceptional."

Hazardous Waste Management Program – Idaho State University (*DPSC* pp. 94–102) [see p. 22] "The Dean of Graduate Studies (now the Dean of Research) was named the program director and given complete control of the budget for the program. An assistant director was appointed and serves as the student advisor at the INEEL [Idaho National Engineering and Environmental Laboratory]. All faculty appointed to serve in the program are approved by the HWM Council and are provided special funds for participation in the program (overload pay, special pay for travel, travel to national meetings, supplies for course work, special opportunities for research funding)."

Information Feedback Mechanisms

A policy that has had, I think, more effect than anything in terms of TA development and preparation programs, has been our adding [the program] to the program review process, with very specific questions, and with site visits by a committee from the Graduate School to see whether in fact those preparation programs are really as they are described in the program review documents. And on top of that, the Graduate and Professional Student Senate now has a questionnaire that goes out to all the departments, and that information, in terms of preparation for TA-ships and preparation for RA-ships, is also included in the program review process. Jody Nyquist

> One comment that resonated with me was Jerry Graff's description of graduate education as a "cottage industry," where little collective information is gathered. I agree with this comment and the importance of this kind of information to graduate programs. I wish we could have discussed some strategies to instigate this change.

Some writers argued that the system needs various types of feedback mechanisms in order to monitor, and make necessary changes to, its programs. For example, they suggested talking to alumni about their education experience, asking what worked and what did not. 'Tracking students to find out what kinds of jobs they have and what requisite skills were needed for their positions is important. People mentioned three types of assessment activity that are needed to inform faculty, departments, and administrations: assessing needs (including students' and society's); tracking alumni careers; and evaluating reform efforts. The following quotations express the concerns about the need for various types of feedback:

> Not many institutions invest a lot of time, money, or energy in assessing what students' needs are—by asking students, or alumni. Without this feedback, the institution has no means of ensuring the quality or relevance of the service it provides. Second, the client/customer is not an informed buyer, and, as economics dictates, imperfect information can cause market failure. Therefore, institutions/universities should believe that information gathering and dissemination are central to their mission. [They need] information about job opportunities, about skill sets required for the types

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of jobs, and about the curriculum's relevance to those job. This information can be best obtained through surveys of alumni and employers. (Abigail Caplovitz)

As suggested by many, tracking of graduates to get a sense of outcomes for students is crucial.

The Serving Students and Society panel elicited the importance of getting good feedback data on (1) how the multitude of current practices in graduate education are impacting/experienced by the diverse participants and (2) outcomes of these programs, with the measurements based on clearly articulated definitions of "success" that are closely aligned with the fundamental values of higher education. I completely agree with these suggestions and can point to data-collection and analysis processes that have substantially improved policy decision-making processes. Providing good data to faculty and to administrators can help them become part of the process. (Susan Mill an)

None of the speakers really addressed [the idea of] evaluation of programs being an integral part of any strategy. This perhaps is the most important phase of any program. Yet, it has been virtually ignored.

While most discussed feedback information in terms of its usefulness to informing the system, a few pointed out yet another benefit of using evaluation data: it can act to bring reluctant faculty on board.

Research is and should be an integral part of a Ph.D. We do not want to weaken the research efforts of an institution or our nation. We have to keep this in mind as we approach faculty and administrators, because raising that issue is a common defense tactic. We need to get hard data on the fact that students who train more broadly still get their degrees in timely fashion and perhaps even contribute more to their department or institution. (Jennifer Miskowski)

DPSC **citations**

Graduate Experience Project – University of Michigan (*DPSC* pp. 25-29) [see pp. 24 and 43] "Evaluating peer advising and mentoring programs can be difficult, since many advisor-advisee interactions can be informal and short term. However, every term peer advisors evaluate their own contacts with students and evaluate the overall peer advisor program."

Hazardous Waste Management Program – Idaho State University (*DPSC* pp. 96102) [see pp. 22 and 34]

Future Professoriate Project – Syracuse University (*DPSC* pp. 146-152) [see p. 48] "Several strategies were employed. . . . Launching a follow-up evaluation plan. Longitudinal case histories of teaching associates involve in-depth interviews at various intervals through their years at Syracuse and their search for a full-time position, and then during the next phase of their professional careers up to the time of the promotion and tenure decision. The data collected will be shared widely with the intent of using it to inform current practices in the project."

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Physical Science Ph.D. Careers: A Qualitative-Quantitative Study – University of Colorado-Boulder (***DPSC*** pp. 172-173) "The NSF spends about a quarter of a billion dollars on graduate education and needs to 'find ways to increase the return to the nation on its investment' (MPS 1995). An important part of this goal should be assure that scientists are able to make use of their graduate training in their careers. . . . [This research] project focuses on two issues: the relationship between graduate education and work activities, and career transitions. . . . One of the most challenging tasks of any evaluation effort is to obtain up-to-date contact information, and our study is no exception. While this is particularly difficult for a research study such as ours, some of the departments participating in our study have contact information, for a high percentage of their recent graduates."

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Appendix I

Participant List by Organization

ABT Associates
Anne Chase

ABT Associates, Inc.
Emorcia V. Hill

Academic and Education Relations
Connie Blackwood

Air Force Institute of Technology/EN
George Haritos

Albert Einstein College of Medicine'
Paula Cohen
Dennis Shields

American Association for Higher Education
Susan Ganter

American Association for the Advancement of Science
Robert Rich

American Chemical Society
Janet Boese
Mary Jordan
Terri Nally
Frank Walworth
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American Institute of Physics
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Arizona State University
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